A COMBINED CLADISTIC ANALYSIS OF ANGIOSPERMS USING *rbc*L AND NON-MOLECULAR DATA SETS[1]

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ABSTRACT

A combined analysis of 162 extant angiosperm taxa for which *rbc*L sequence-data and/or an appreciable amount of non-molecular information is available was calculated. A non-molecular tree, an *rbc*L tree, and a combined tree are presented. Only the *rbc*L and the combined data set show large numbers of groupings with bootstrap percentages greater than 50%, whereas the non-molecular trees show only eleven clades of this kind; this seems due to the number of missing cells in the non-molecular matrix. We tried to identify non-molecular characters (including biochemical) that support groups present in these analyses, especially in cases where clades turned out to be new when compared to one or more "classical" taxonomic systems. New groupings found in the non-molecular analysis that parallel the *rbc*L topologies include a grade containing Illiciales, Austrobaileyaceae, and Amborellaceae (magnoliid II); a clade containing Magnoliales, Laurales, Aristolochianae, and monocots (magnoliid I); a hamamelid group; subgroups of asterids (e.g., a similar asterid III clade containing Scytopetalaceae, Lecythidaceae, Sapotaceae, Ebenaceae, Theaceae, Primulales, Styracaceae, Marcgraviaceae, Actinidiaceae, Clethraceae, and Ericales); an expanded caryophyllid group; a Malvales s.l. clade; a partial Malpighiales grade containing Quiinaceae, Linales s. str., Passiflorales, Violaceae, Kiggelariaceae, Flacourtiaceae s. str., and Ochnaceae; and some smaller clades, similar to the corresponding groups found in *rbc*L cladograms (Illiciales–Austrobaileyaceae; Aristolochianae–monocots; Hydrangeaceae–Cornales; Lecythidaceae–Scytopetalaceae; Pittosporaceae–Araliales; Geissolomataceae–Stachyuraceae; Connaraceae–Oxalidaceae). Capparales s.l. and the nitrogen-fixing clade, two novel molecular clades, are only found in the *rbc*L and the combined trees. Cistaceae have been shown to share important characters with Malvales s.l. and are consistently found within this clade. These findings argue against their previous inclusion in Violales. The *rbc*L tree contains 38 terminal taxa that are included for the first time in a published phylogeny. Considerable progress has been made in assembling a morphological/chemical data set that parallels the broad coverage of angiosperms seen in DNA studies.

New opportunities for the study of seed-plant phylogeny have opened due to the continued development of computer hardware and software. In addition, gene sequencing has become reasonably fast, and large nucleotide data matrices have been produced (e.g., Chase et al., 1993; Savolainen et al., 1996; Soltis et al., 1997b). These studies have stimulated even more molecular work on macrosystematics, including the addition of more "critical" taxa to the data matrices, comparison with results from other gene sequences, and the combination of nucleotide with non-molecular data matrices, as has been undertaken in this study. Other examples of broadly sampled combined nucleotide and non-molecular studies are those of Doyle et al. (1994) and Chase et al. (1995).

The non-molecular investigations of this study originated from the question of the position of Cistaceae within eudicots. Cistaceae have been included in Violales (Takhtajan, 1966; Cronquist, 1981) and Malvales (Dahlgren, 1980), yet the most natural (i.e., phylogenetic) position has remained a matter of debate (Thorne, 1983, 1992). Thus, it was a major objective of our non-molecular study to identify the accurate position of Cistaceae and their allies (Bixaceae and Cochlospermaceae) within the eudicots. Most families that have commonly been allied with Malvales or Violales are included in

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the present study. Many more taxa were added to evaluate the robustness and position of the two orders within eudicots and to compare the trees obtained with other studies (Hufford, 1992; Olmstead et al., 1992; Albert et al., 1992; Chase et al., 1993).

Monophyly of the taxa used has also been evaluated by comparing molecular results with macrosystematic studies (e.g., Urticales: Berg, 1977). This was done to determine which terminal taxa should be used in the non-molecular sampling. In the non-molecular matrix we make use of those clades found in the *rbc*L analysis that are compatible with widely accepted groups. Thus in some cases we have sampled individual families, whereas in others we have used orders (e.g., Gentianales, Annonales, etc.), superorders (e.g., Faganae, Aristolochianae), or larger groups (e.g., monocotyledons) that no recent research (molecular or non-molecular) has indicated are other than monophyletic. Flacourtiaceae s.l. were split into two groups, one with cyanogenic glycosides (e.g., Kiggelariaceae) and one without.

A major caveat for the non-molecular matrix is that we often used single character-states for polymorphic taxa. These assignments are based on assumptions of character polarity, which could result in mistaken interpretations of character evolution. We accept that in some specific cases mistakes may have been made, but we felt that some simplifications were required to deal with such large taxonomic units. However, the character-state assignments were carried out using a consistent approach (see Appendix 5). Because the independent trees are often highly similar, we gain confidence that the historical signal present in the non-molecular data has not been grossly distorted by this method of character-state assignment. We hope that further progress in non-molecular investigations will obviate the need for such a procedure in future studies. We are certain that this approach can be greatly improved upon. Analysis of large, non-molecular matrices is not without precedent in plant systematics (e.g., Donoghue & Doyle, 1989). Working with such large non-molecular matrices could have undesirable effects (i.e., not finding the shortest trees or all islands of trees, cf. Maddison, 1991). These large matrices must nonetheless be much less confounding than matrices using exemplar taxa for groups that are not monophyletic.

We were interested in finding a large set of non-molecular characters that would contain phylogenetic information. We tried to characterize larger taxonomic groupings, especially new ones, by non-molecular synapomorphies, as produced by MacClade 3.04 (cf. Maddison & Maddison, 1992). We wanted to see in which way the non-molecular data set changed or confirmed the topology of the *rbc*L tree, and vice versa, when both data sets are combined (we agree that the inclusion of *rbc*L results in delimiting the terminal taxa and in looking for taxa with more ancestral characters within the larger of these terminal taxa makes it impossible to claim that both data sets are totally independent). We also examined by simple comparison whether the different samplings of taxa in the *rbc*L analysis of Chase et al. (1993) and that of the present study affect the topology of the *rbc*L tree. Finally, we were also interested in the stability of the topologies obtained after applying the parsimony jackknife program (Farris et al., 1997) and bootstrapping (Felsenstein, 1985).

Material and Methods

General methods

The matrices were analyzed using PAUP 3.1.1 (Swofford, 1993). The shortest trees were collected and swapped on to completion, keeping in this case all additional trees found at this shortest branch length. In the Results and Discussion sections, we will mostly use the same terms for the larger angiosperm clades used by Chase et al. (1993: part B of figs. 1–15) to facilitate comparisons.

Ceratophyllum was specified as the outgroup in agreement with the results produced with *rbc*L (Chase et al., 1993). We simply used *Ceratophyllum* as the outgroup to avoid the issue of where in the angiosperms the root should be placed. This topic will be discussed in other papers; we view it as too complex an issue to be dealt with adequately here. The use of non-angiosperm outgroups (Gnetales) for the non-molecular matrix is difficult. Important morphological structures cannot be adequately addressed in terms of their homology at present. Because we used *Ceratophyllum* as the default outgroup, we will not concern ourselves with the evaluation of its position. We were interested only in examining general patterns within the angiosperms for both *rbc*L and non-molecular data. All matrices are available on diskette or by e-mail (m.chase@rbgkew.org.uk) from the second author (please provide a single high-density diskette).

In each case, the products of the initial searches were sets of trees with equally weighted characters.

We intended to use the jackknife procedure of Farris et al. (1997) but found that the number of missing cells in these matrices makes this method unsuitable because it found no support for any groupings in the combined matrices [J. Farris, pers. comm., reports that missing data significantly lower

jackknife values; we have also investigated this empirically in another study (Fay et al., 1997)]. We therefore used the bootstrap consistently for an easier comparison. For trees illustrated in this paper, branch lengths are shown above the branches (ACCTRAN optimization, Swofford, 1993), and all branches not present in the strict consensus trees are indicated by an arrow. Bootstrap support for supported groups is indicated below the branches.

NON-MOLECULAR DATA MATRIX (APPENDIX 1)

A selection of 161 angiosperm taxa was scored for 252 characters (Appendix 3); 151 taxa were ultimately included in the non-molecular search (115 families, 32 orders, and 4 supraordinal taxa, mainly in the sense of Takhtajan, 1987; Appendix 2). Data were taken from selected synoptic literature, from primary literature (especially in dilleniids sensu Cronquist, 1981) and from original observations by the first author [leaf venation and dentation (studied in the Herbaria of Zürich, Geneva, and Vienna and in a number of botanical gardens) and observations from anatomical sections or SEM micrographs in Cistaceae, Cochlospermaceae, Bixaceae, Dipterocarpaceae, Sarcolaenaceae, Sphaerosepalaceae, and Berberidopsidaceae]. We had also at hand the extensive anatomical slide collection of the third author. Uncertain cases with regard to the presence or absence of oxalate crystals and to ovule anatomy were resolved by careful observation of selected slides (e.g., oxalate crystals seem to be absent from *Amborella*; see also Metcalfe, 1987).

We used the characters that we considered to contain the most significant phylogenetic information. Floral developmental information could only be scored with two characters (characters 223 and 224 in the matrix) due to the complexity of comparing developmental data. Characters were grouped into the following classes: 1. Serology (16 characters); 2. Chemical compounds (88 characters); 3. Characters at cellular level (22 characters); 4. Embryology (18 characters); 5. Seed anatomy (21 characters); 6. Stem morphology and anatomy (24 characters); 7. Leaf characters (17 characters); 8. Floral and fruiting characters (46 characters). The procedure of assigning character-states to taxa is documented in more detail in Appendix 5, but in general the hypothesized plesiomorphic state was used if more than one state occurred within a terminal taxon. In a few cases, paleobotanical information was also included (e.g., Magnoliaceae, Platanaceae, Buxaceae; Crane, 1989; Crane et al., 1993; Drinnan et al., 1991; Dilcher & Crane, 1984).

Most of the characters are mutually independent. Other characters were chosen as hierarchical sets (e.g., characters 8–10, 80–85, 97–100, 200–202, or 250–251), character pairs (223–224), or character triplets (108–110, 142–144). Compatibility with the molecular data set was reached by only allowing four character-states ("A," "C," "G," "T"). "A" can be equated to "0," "C" to "1," "G" to "2," and "T" to "3". Characters with more than four states were broken up into character sets (233–235), but few characters required such modification.

Of the 252 characters, 207 are binary (in 186 of these simple presence/absence coding is involved) and 45 are multistate characters. The common strategy of character-state assignment described in Appendix 5 was to find a basal pattern for each taxon. With this procedure, we tried to reduce character radiation due to the evolutionary processes within the terminal taxon. In characters with states that have low probability to be evolved, due to their complexity, presence of a state was favored in coding over absence of a state (e.g., presence of phloem stratification; 169; presence of bixoid exotegmen in the chalazal region; 159; presence of salicoid leaf dentation; 201). This implied that the character was coded as being present if at least one representative of the terminal taxon is known to exhibit the character-state. By analogy, for dithetic characters, in which both states are more or less equally likely to have evolved, the character was coded as polymorphic if both character-states occur in a terminal taxon (e.g., successive or simultaneous microsporogenesis; 128). More specific rules, which were rarely applied to cover more complex hypotheses of character evolution, are given in Appendix 5. These exceptions were applied restrictively, since the number of assumptions prior to analysis of data should be low. Appendix 5 also lists characters for which the putative ancestral character-state was searched by scoring the character-state in putatively basal members of the terminal taxon (e.g., Ulmaceae in Urticales, *Ceratonia* in Fabaceae, *Erythrospermum* in Kiggelariaceae).

Biochemical characters were scored as absent, present, or "?" (unknown or uncertain) in certain terminal taxa by considering the extent of knowledge of the biochemical substance classes in question (in the specific taxon). In wood anatomy, the broadly acknowledged evolutionary trends (see e.g., Carlquist, 1988a: chapter 11) from ancestral to derived character-states were used strictly to find character-states of terminal taxa [i.e., uni-or biseriate circular or scalariform vessel side-wall pitting was preferred over opposite, and opposite over al-

ternate (184); vessellessness was preferred over presence of vessels (integrated in 185); scalariform perforation plates were preferred over mixed scalariform and simple plates, and the latter over simple plates (185)].

All characters were scored as unordered. Ambiguous characters for which no priority rule was applied (see Appendix 5) were coded as polymorphic. Assignment of character-states was complicated by the fact that often only the presence (and not the absence) of a character-state is noted in the literature. If one or more thorough published studies of a character class in a certain terminal are available, and a given character-state was not described, it was coded as being absent. This rule was applied to, for example, presence or absence of exotegmic palisades or exotegmic longitudinal fibers in seeds (157). Some extrinsic characters such as hostplant and paleobotanical data were not included in the matrix, but their optimization was evaluated from the trees produced.

Information on taxon circumscription, characters and character-states (including four data errors that were detected after all analyses were completed), character definitions, procedures of character-state assignment, and sources are given in Appendices 2–6. The four errors were examined for effects by initiating searches on the trees found; we found no additional or shorter trees, so we assumed that complete new searches were not warranted.

In Search I, 100 random-addition replicates were run using TBR branch swapping (Swofford, 1993), but keeping only 10 trees per step (TBR = tree bisection-reconnection). The first tree of the shortest tree set obtained was swapped to completion (i.e., MULPARS turned on; Swofford, 1993). The steepest descent option (Swofford, 1993) was not used. This island that was found (sensu Maddison, 1991) contained 136 trees of length 3546, consistency index (CI) = 0.09, and retention index (RI) = 0.41.

In Search II, 1000 random-addition replicates were run using SPR algorithm and keeping only 1 tree per step (SPR = subtree pruning-regrafting; Swofford, 1993). The shortest tree was swapped to completion with MULPARS turned on. The steepest descent option was not used. The resulting island obtained with this method contained 8 trees of length 3545, CI = 0.09, and RI = 0.41.

These two searches were very slow (much slower than the *rbc*L and combined searches), and we suspected that shorter trees could be produced by another strategy, described below.

In Search III, the taxa were divided into three groups. Group I contained taxa 1 to 37 (presumed magnoliids, lower eudicots, and caryophyllids). Group II contained taxa 38 to 106 and taxa 149, 150, 161 (presumed rosids). Group III contained taxa 107 to 148 (presumed asterids). First, group II was processed. One hundred random-addition replicates were done using the TBR algorithm and keeping maximally 10 trees per step. The topology of the strict consensus of the shortest tree set (containing two most-parsimonious trees) was defined as a constraint framework for the following step. The taxa of group I were added. One hundred random-addition replicates were done with TBR swapping and keeping maximally 10 trees per step. After this, the constraints were omitted and all taxa of the first tree of the shortest tree set obtained were allowed to swap freely to completion using the TBR algorithm. The resulting tree set was defined as a constraint for the following step, with the taxa of group III added. One hundred random-addition replicates were done with TBR swapping but keeping maximally 10 trees per step. The constraints were omitted again, and all taxa of the first tree of the shortest tree set obtained were allowed to swap freely to completion using the TBR algorithm. The trees obtained were 3544 steps long. This tree set was reweighted based on the rescaled consistency index with maximal weight of 10. Twenty steps of length reduction were done with this new weight set using the TBR algorithm. After this, all characters were again weighted equally. The trees obtained in the last procedure were swapped to completion. More than 2200 trees of length 3541 were obtained. The search was stopped due to memory constraints. The first 50 trees of the obtained tree set were reweighted based on the rescaled consistency index with maximal weight of 100. Twenty steps of length reduction were done with this new weight set using the TBR algorithm. Afterward all characters were again weighted equally. The trees obtained in the

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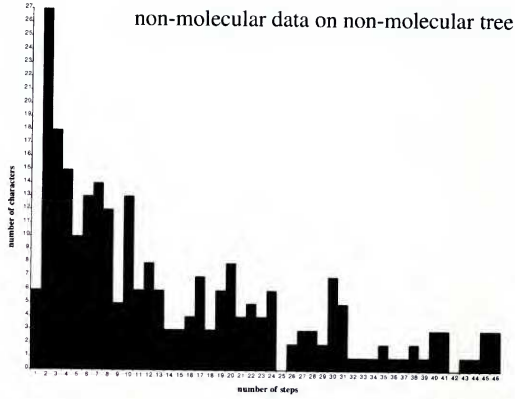
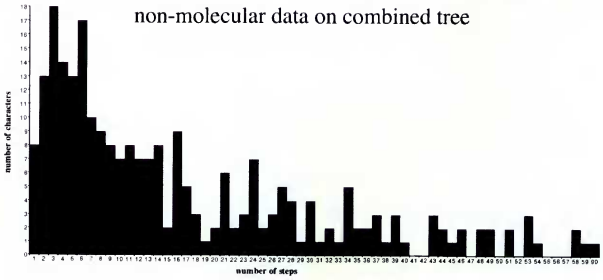
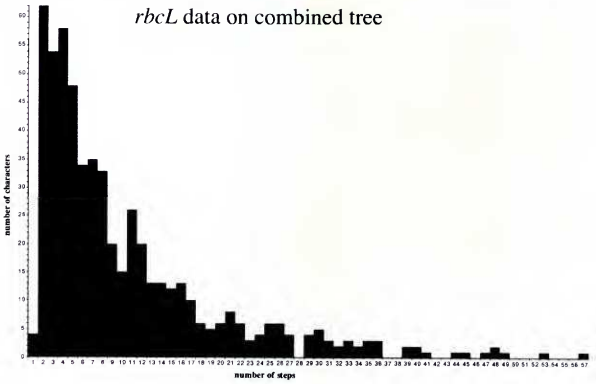
Figure 1. As evidence in support of the use of successive weighting, we used MacClade 3.06 (Maddison & Maddison, 1992) to plot how many steps were contributed by informative characters in each data matrix. In part B, for example, eight characters in the non-molecular matrix were changing one time when these data were optimized on the combined tree, whereas one character was changing 60 times. —A (top). The non-molecular data optimized on one of the shortest trees found with the non-molecular data only. —B (middle). The non-molecular data optimized on a tree from the combined analysis. —C (bottom). Plot of the *rbc*L data mapped onto the combined tree.


non-molecular data on non-molecular tree
number of characters
number of steps


non-molecular data on combined tree
number of characters
number of steps


rbcL data on combined tree
number of characters
number of steps

last procedure were swapped to completion. The steepest descent option was also not used in Search III. An ultimate tree set of 17 trees with a length of 3539, CI = 0.09, and RI = 0.41 was obtained; the first tree of this set is illustrated in Figure 2. Arrows indicate groups not found in all 17 trees. This is obviously only one island of many that exist for this data set, but it is the shortest tree length that we were able to obtain, and in spite of the unorthodoxy of the procedure, it produced far shorter trees than any "standard" method (i.e., with replicates of random taxon-addition). The three taxon-groups in Search III were formed by comparison with *rbc*L topologies. This introduces some bias in the non-molecular trees, but the application of these three groups was responsible for finding the shortest trees.

MATRICES FOR *rbc*L AND COMBINED DATA

The techniques involved in collecting our *rbc*L data have been previously published (Chase et al., 1993; Chase et al., 1995). Because each *rbc*L sequence represents a specific single plant (Appendix 7), which we assume can represent its family or other higher taxon, we used a single *rbc*L sequence to represent each of the terminals scored in the non-molecular matrix. In general, we selected as the *rbc*L representative a species that was not especially sequence-divergent within its group. Many of the sequences included in the present study are previously unpublished. We analyzed this new *rbc*L matrix to be certain that we could obtain results similar to those of other published *rbc*L topologies. Taxa for which we still have no molecular data are marked with "§" in Figure 4 A, B.

Problems in amalgamating nucleotide and non-molecular data sets are discussed in Chase et al. (1995). The main problem is that non-molecular characters were scored for higher taxa whereas each *rbc*L sequence represents a single plant. In our experience, this technique does not appear to produce spurious results (several such studies have been published and more are in progress in the laboratory of M. Chase; Chase et al., 1995; Gadek et al., 1996; Morton et al., 1997). The trees obtained with more taxa, thus spanning the divergence levels present within a family, do not produce wildly different patterns, nor does substitution of one species in a family for another greatly affect the position of the family (provided the family is monophyletic). This fact is obvious when one compares the patterns found for multiple members of a family in the 1993 *rbc*L tree (Chase et al.) with the position of that family in the present analysis, in which only one taxon was included. Furthermore, there should be no expected correspondence between a morphologically plesiomorphic taxon and plesiomorphic molecular characters, so taxon selection based on presumed "basalness" is not an important consideration. However, if faced with a choice between species that are highly divergent and others that are only slightly divergent, then use of one of the latter is helpful in avoiding spurious placements of the family.

We excluded the first 27 base positions at the 5′ end of *rbc*L, leaving a maximum of 1401 basepairs (bp) of data for each species (some were less than this, although none substantially less than 1300 bp). Of these 1401 sites, 785 (56%) were variable and only 562 (40%) were potentially informative.

We used 1000 replicates of random-taxon entries and the TBR-swapping algorithm; only five trees were retained per step, which reduces the amount of time spent swapping on trees from suboptimal tree islands (Maddison, 1991). Although all trees shown were produced by successive weighting, we have shown them with their Fitch branch lengths (Fitch, 1971; i.e., characters with equal weights, character-states unordered) in Figures 3 and 4. In all but the strictly non-molecular matrix, we employed successive weighting to down weight or eliminate the effects of characters that changed excessively (Farris, 1969; Carpenter, 1988, suggested that successive weighting should be used merely to select a subset of the trees found with equal weights). To illustrate the reasons why we favor the use of successive weighting, we plotted the number of steps vs. the number of characters in MacClade 3.06 (Maddison & Maddison, 1992) for both the non-molecular and the *rbc*L matrices (both on the combined tree and on the shortest non-molecular trees). Once excessively homoplasious characters were down weighted, it was logical not to use those characters in estimating internal support. Hence relative weights were employed in the bootstrapping procedure (5000 replicates for each matrix) except for the non-molecular matrix, which was evaluated with equal weights. The rescaled consistency index (RC; Swofford, 1993) was used to calculate the successive weights (with a base weight of 1000) based on the best fit in any tree for each character, and in bootstrapping characters were sampled with equal probability rather than having the frequencies depend on the weights. We used a "fast" bootstrapping procedure in which a minimal amount of NNI swapping was used (the fastest and most superficial of the PAUP swapping algorithms; we permitted only 20 trees to be retained at each step). This procedure obviates the need to swap

extensively, significantly shortening the time to carry out bootstrapping. Well supported groups are present in the starting trees (due to the quick distance-based calculations that PAUP and other parsimony programs use to generate a tree upon which swapping is then carried out) and do not need any swapping to be identified. If extensive swapping is required to "find" groups, then they are obviously weakly supported or unsupported; groups with intermediate levels of support necessitate at least some swapping to be effectively evaluated, hence the limited use of NNI swapping. We expect that the use of successive weighting will in many cases, as here, find trees for which the Fitch lengths (equal weighting) are longer than for the shortest trees found with Fitch parsimony. This is due to the fact that when highly homoplasious characters are down weighted, more consistent characters (those with higher relative weights) will be optimized more parsimoniously, thus forcing more changes into already highly homoplasious characters because such actions actually reduce the weighted tree length. Some characters in these matrices do change excessively often (see Results below), and thus it seems logical to us that once we have eliminated the effects of highly variable characters in the tree search procedure, these weights should be employed as well to evaluate internal support. Characters that change as often as 40–60 times should be eliminated from consideration; it seems obvious to us that these characters are not useful at this taxonomic level. In the interests of retaining a reasonable lack of a priori sifting of characters, we kept all characters until the initial patterns obtained indicated a lack of appropriateness of some data (such winnowing is of course not possible with DNA data unless one resorts to whole-category weights, and we do not find any evidence that such weighting schemes are appropriate; Chase et al., 1995, found that third codon positions in *rbc*L were better phylogenetic data than first or second positions).

Results

Amounts of homoplasy

The numbers of times each character of the non-molecular or of the molecular matrix changed on different trees are illustrated in Figure 1. As estimated on the combined tree found with successive weighting, some characters in the non-molecular matrix were changing up to 60 times (Fig. 1B); in the *rbc*L matrix, fewer sites were changing as frequently, although one site did change 57 times (Fig. 1C). For the non-molecular data, 26.0% of the characters changed five times or less (Fig. 1B; versus 30.3% on the shortest non-molecular tree, Fig. 1A), and 26.4% of the *rbc*L characters fell into this same category. Examples of non-molecular characters that changed frequently are distributed among different character types; pollen: polar pollen diameter (131) changed 45 times, and sexine texture (135) changed 45 times; seed anatomy: ovular or seed vascular bundles (145) changed 45 times, and embryo size (163) changed 45 times; wood anatomy: wood parenchyma (174) changed 46 times; fruits: seed to carpel number (249) changed 45 times. None of the serological or chemical characters changed more than 28 times. Both molecular and non-molecular data had nearly the same percentage of reasonably non-homoplasious characters, but many of the non-molecular characters possessed only two alternate states; therefore when these characters change two or more times homoplasy is involved, whereas base positions in DNA sequences can change up to three times without producing any homoplasy (e.g., from A to C, A to G, and A to T). Thus this comparison of percentages of numbers of steps is not entirely accurate, but the complexity involved in comparing multistate with binary patterns is too high to be discussed here. It should be noted that with successive weighting of nucleotides based on the RC those changing three times uniquely (e.g., from A to C, A to G, and A to T) retain the same weight as those changing only once, whereas binary characters that change three times will be drastically down weight-

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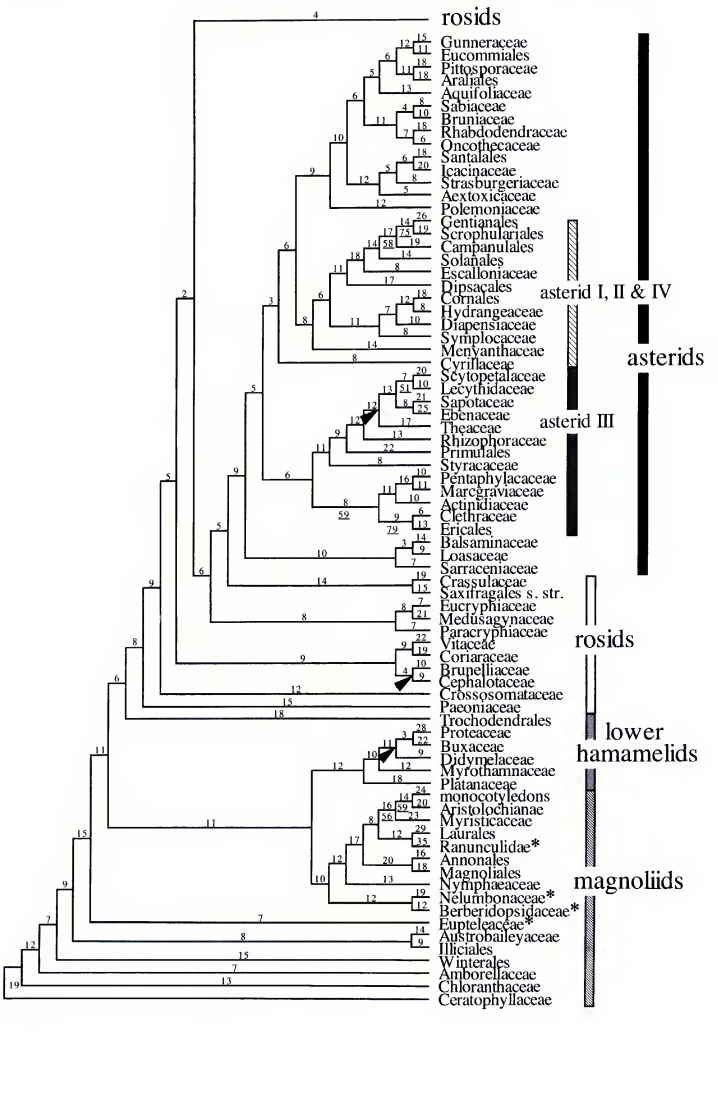
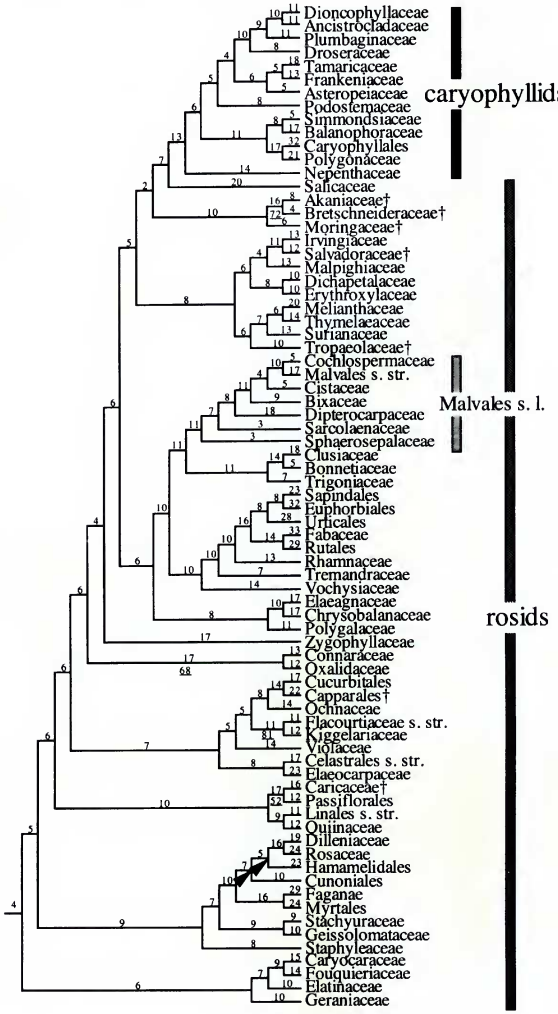
Figure 2. One of seventeen equally most-parsimonious trees derived from the non-molecular matrix in Search III found with equally weighted characters. These trees have 3539 steps with CI = 0.09 and RI = 0.41. Branches not found in all seventeen trees are marked with an arrow. Numbers above the branches are the numbers of estimated substitutions (ACCTRAN optimization). Underlined numbers below branches are bootstrap values; branches without an underlined number had bootstrap percentages of less than 50%. —A (left). First-branching portion of the tree, arranged with Ceratophyllaceae as the outgroup. Magnoliids and hamamelids form a grade, out of which most of the eudicots are derived. Within eudicots, rosids form a grade in which the asterids and caryophyllids are embedded. —B (right). Mostly rosid, derived clade. *Triaperturate taxa embedded within uniaperaturate grade. †Glucosinolate-producing taxa.


rosids
Gunneraceae
Eucommiales
Pittosporaceae
Araliales
Aquifoliaceae
Sabiaceae
Bruniaceae
Rhabdodendraceae
Oncothecaceae
Santalales
Icacinaceae
Strasburgeriaceae
Aextoxicaceae
Polemoniaceae
Gentianales
Scrophulariales
Campanulales
Solanales
Escalloniaceae
Dipsacales
Cornales
Hydrangeaceae
Diapensiaceae
Symplocaceae
Menyanthaceae
Cyrillaceae
Scytopetalaceae
Lecythidaceae
Sapotaceae
Ebenaceae
Theaceae
Rhizophoraceae
Primulales
Styracaceae
Pentaphylacaceae
Marcgraviaceae
Actinidiaceae
Clethraceae
Ericales
Balsaminaceae
Loasaceae
Sarraceniaceae
Crassulaceae
Saxifragales s. str.
Eucryphiaceae
Medusagynaceae
Paracryphiaceae
Vitaceae
Coriariaceae
Brunelliaceae
Cephalotaceae
Crossosomataceae
Paeoniaceae
Trochodendrales
Proteaceae
Buxaceae
Didymelaceae
Myrothamnaceae
Platanaceae
monocotyledons
Aristolochianae
Myristicaceae
Laurales
Ranunculidae*
Annonales
Magnoliales
Nymphaeaceae
Nelumbonaceae*
Berberidopsidaceae*
Eupteleaceae*
Austrobaileyaceae
Illiciales
Winterales
Amborellaceae
Chloranthaceae
Ceratophyllaceae
asterid I, II & IV
asterids
asterid III
rosids
lower hamamelids
magnoliids


Dioncophyllaceae
Ancistrocladaceae
Plumbaginaceae
Droseraceae
Tamaricaceae
Frankeniaceae
Asteropeiaceae
Podostemaceae
Simmondsiaceae
Balanophoraceae
Caryophyllales
Polygonaceae
Nepenthaceae
Salicaceae
Akaniaceae†
Bretschneideraceae†
Moringaceae†
Irvingiaceae
Salvadoraceae†
Malpighiaceae
Dichapetalaceae
Erythroxylaceae
Meliaceae
Thymelaeaceae
Surianaceae
Tropaeolaceae†
Cochlospermaceae
Malvales s. str.
Cistaceae
Bixaceae
Dipterocarpaceae
Sarcolaenaceae
Sphaerosepalaceae
Clusiaceae
Bonnetiaceae
Trigoniaceae
Sapindales
Euphorbiales
Urticales
Fabaceae
Rutales
Rhamnaceae
Tremandraceae
Vochysiaceae
Elaeagnaceae
Chrysobalanaceae
Polygalaceae
Zygophyllaceae
Connaraceae
Oxalidaceae
Cucurbitales
Capparales†
Ochnaceae
Flacourtiaceae s. str.
Violaceae
Celastrales s. str.
Elaeocarpaceae
Caricaceae†
Passiflorales
Linales s. str.
Quiinaceae
Dilleniaceae
Rosaceae
Hamamelidales
Cunoniales
Fagaceae
Myrtales
Stachyuraceae
Geissolomataceae
Staphyleaceae
Caryocaraceae
Fouquieriaceae
Elatinaceae
Geraniaceae
caryophyllids s. l.
Malvales s. l.
rosids

ed. The main point here is that successive weighting is based on the rescaled consistency index. This permits the dissection of patterns of change more accurately than merely eliminating base positions that change excessively. Weighting with the RC is also much more appropriate for DNA sequences than simple weighting with CI. Furthermore, merely eliminating all characters that change more than a certain arbitrarily set number of times (e.g., more than ten times) will eliminate some characters with multiple states (e.g., nucleotides) that retain a great deal of signal.

NON-MOLECULAR DATA MATRIX AND TREES

In the construction of the non-molecular matrix, some original observations, mainly in Malvales and Violales, were made. The observations on the placement of Cistaceae applying cladistic methods are convincingly supported by specialized synapomorphies. A seed with a specialized structure in the chalazal region (an exotegmic palisade layer curved inward at the chalaza, and with a hypostase plug fitting into this dome-shaped curvature), was found in the seeds of several taxa (159). We termed this chalaza structure a bixoid chalaza (Nandi, 1998a). The occurrence of this chalaza type was known for Bixaceae, Cochlospermaceae, and Cistaceae. We found it also in Pakaraimaeoideae and Monotoideae (Dipterocarpaceae) and in Sarcolaenaceae (the character-state for Sarcolaenaceae was not included in the data matrix because it was found after the processing of the matrix). In Flacourtiaceae, salicoid leaf dentation (201, definition see Appendix 4) was found in twelve more genera not previously known to exhibit this condition: *Dissomeria, Byrsanthus, Calantica, Carriera, Flacourtia* (only some species), *Homalium, Ludia* (not well developed), *Oncoba, Poliothyrsis, Scolopia, Trimeria*, and *Xylosma*.

One of the 17 most-parsimonious trees (the first one found during the search) from Search III of the non-molecular analysis is shown in Figure 2. It has a length of 3539 steps, CI = 0.09, and RI = 0.41. Branches not found in all 17 trees are indicated by solid arrows. Judging from the bootstrap results, internal support for this topology is weak; only eleven groupings received bootstrap support of 50% or greater: Myristicaceae/Aristolochianae/monocotyledons (56%), Aristolochianae/monocotyledons (59%), Clethraceae/Ericales/Actinidiaceae/Pentaphylacaceae/Marcgraviaceae (59%), Clethraceae/Ericales (79%), Scytopetalaceae/Lecythidaceae (51%), Campanulales/Gentianales/Scrophulariales (58%), Gentianales/Scrophulariales (75%), Caricaceae/Passiflorales (52%), Connaraceae/Oxalidaceae (68%), Flacourtiaceae s. str./Kiggelariaceae (81%), and Akaniaceae/Bretschneideraceae (72%).

Dilleniids sensu Takhtajan (1966) and Cronquist (1981) were not recovered in this analysis, and we thus treat the eudicots as being composed of ranunculids, hamamelids, caryophyllids, rosids, and asterids; we use the narrower categories (i.e., asterid I, rosid II, etc.) as necessary.

New groupings that are similar to those obtained from *rbc*L studies are a grade containing Illiciales, Austrobaileyaceae, and Amborellaceae (magnoliid II), a clade containing Magnoliales, Laurales, Annonales, Aristolochianae, and monocots (magnoliids I), a lower hamamelid group, a number of subgroups of asterids (e.g., a similar asterid III clade containing Scytopetalaceae, Lecythidaceae, Sapotaceae, Ebenaceae, Theaceae, Primulales, Styracaceae, Marcgraviaceae, Actinidiaceae, Clethraceae, and Ericales), an expanded caryophyllid group, a Malvales s.l. group, a partial Malpighiales grade containing Quiinaceae, Linales s. str., Passiflorales, Violaceae, Kiggelariaceae, Flacourtiaceae s. str., and Ochnaceae, as well as some smaller clades (Hydrangeaceae–Cornales, Lecythidaceae–Scytopetalaceae; Pittosporaceae–Araliales; Geissolomataceae–Stachyuraceae; Connaraceae–Oxalidaceae). Chloranthaceae appear consistently as an isolated family.

The uniaperturate magnoliids plus the monocots form a grade and not a clade, although a large portion of them do form a monophyletic group. The early-branching taxa include Chloranthaceae, Amborellaceae, Winterales, and Illiciales/Austrobaileyaceae; if the root belongs elsewhere, then Ceratophyllaceae would be a member of a group with these taxa. Certain triaperturate groups (i.e., eudicots) also fall into this grade; these include most of the "lower" hamamelids, plus Ranunculidae, Nelumbonaceae, Berberidopsidaceae, and Eupteleaceae (Fig. 2A). The rosids also form a grade that gives rise on the one hand to the asterids and on the other hand to the expanded caryophyllids (Caryophyllidae s.l.). The composition of Caryophyllidae s.l. is remarkable in the number of groups never associated previously as a whole in any traditional classification with Caryophyllales (Fig. 2B). These include Dioncophyllaceae, Ancistrocladaceae, Droseraceae, Nepenthaceae, Tamaricaceae, Frankeniaceae, Asteropeiaceae, Podostemaceae, Simmondsiaceae, and Balanophoraceae.

An expanded Malvales complex (Malvales s.l.) is present among the rosids (Fig. 2B), but many other groupings within the rosids found in *rbc*L trees are not evident in the non-molecular trees. In particular, the smaller groupings of rosids (rosids I, II, III)

are not evident, nor are the clades composed of glucosinolate-producing (Rodman et al., 1993) or nitrogen-fixing families (Soltis et al., 1995b).

The composition of the expanded asterid assemblage contains many of the same groupings seen in the *rbc*L trees, in particular the asterid III grouping composed of Ericales, Ebenales, Primulales, and some Theales. In addition, several other taxa are also present here that would not be expected, either on the basis of molecular studies or previous taxonomies. These include Gunneraceae, Sabiaceae, Santalales, Oncothecaceae, Aextoxicaceae, Bruniaceae, and Rhabdodendraceae.

*rbc*L TREES

The Fitch search of the *rbc*L matrix produced more than 5000 trees of 6057 steps, CI = 0.22, and RI = 0.43 (the search was discontinued at 5000 trees because the memory was becoming too low; all 5000 were swapped on to completion). Several characters changed more than 40 times (Fig. 1C). After down weighting by the use of successive weighting only nine trees were found. These nine had 6091 Fitch steps, CI = 0.22, and RI = 0.42 (weighted length of 531,123 steps, CI = 0.62, RI = 0.65). Branches not found in all nine weighted trees are marked with arrows (Fig. 3A). The first tree found at this length is illustrated in Figure 3 (ACCTRAN optimization). These trees are in general agreement with the results of Chase et al. (1993). The magnoliids form an unsupported monophyletic clade (bootstrap of less than 50%) that is sister to all eudicots, which are strongly supported (97%). Within the magnoliids, Laurales are sister to the monocotyledons; this is different from either of the two searches presented in Chase et al. (1993), but the present study uses different taxa, and in all cases this grouping is unsupported in the present *rbc*L tree (bootstrap of less than 50%). The relationship between Annonales, Magnoliales, and Myristicaceae has some bootstrap support (63%). Weak support (56%) is also shown for the association of the strongly supported pairs Nymphaeaceae/Amborellaceae (92%) and Illiciales/Austrobaileyaceae (98%).

Ranunculidae/Eupteleaceae (supported at 86%) are sister to the rest of the eudicots. The lower hamamelids form a grade between Ranunculidae/Eupteleaceae and asterids/caryophyllids/rosids. Among hamamelids, Buxaceae are strongly supported (82%) as sister to Didymelaceae; Sabiaceae and Proteaceae are weakly supported (53%) as a clade. The clade of Gunneraceae/Myrothamnaceae is also supported to a similar degree (63%). Berberidopsidaceae/Aextoxicaceae form a pair without internal support, which is the sister group to the rest of the asterids.

The only newly added family that falls into the asterid I and II clades is Icacinaceae. Within the asterids, Gentianales/Solanales/Scrophulariales are weakly supported (67%), as is a relationship of Dipsacales (59%) to Pittosporaceae/Araliales, a pair which has high support (95%). In general, this analysis of *rbc*L does not recover exactly the same relationships within the asterid I and II groups as in Chase et al. (1993), but the sampling is much more sparse here. The asterid IV group of Cornales/Hydrangeaceae is also recovered, but is not supported by the bootstrap.

The asterid III grouping is weakly supported (52%), and there are additional families comprising this group that were not covered in Chase et al. (1993). These include Pellicieraceae, Tetrameristaceae, and Marcgraviaceae, which are strongly supported (100%) in a clade including Balsaminaceae; the first two are also strongly supported (87%) as sister families. Lecythidaceae and Scytopetalaceae are also strongly supported (99%) as sister families, but other recent research (Morton et al., 1997) demonstrated that the latter is embedded in the former. Diapensiaceae are weakly supported (65%) as the sister of Sarraceniaceae, and the pairs Ericales/Actinidiaceae and Clethraceae/Cyrillaceae are also weakly supported (58% and 64%, respectively).

The expanded caryophyllid clade first identified in Albert et al. (1992) and further investigated in Williams et al. (1994) received weak internal support in this analysis (69%). Additional newly identified members of this clade include Tamaricaceae/

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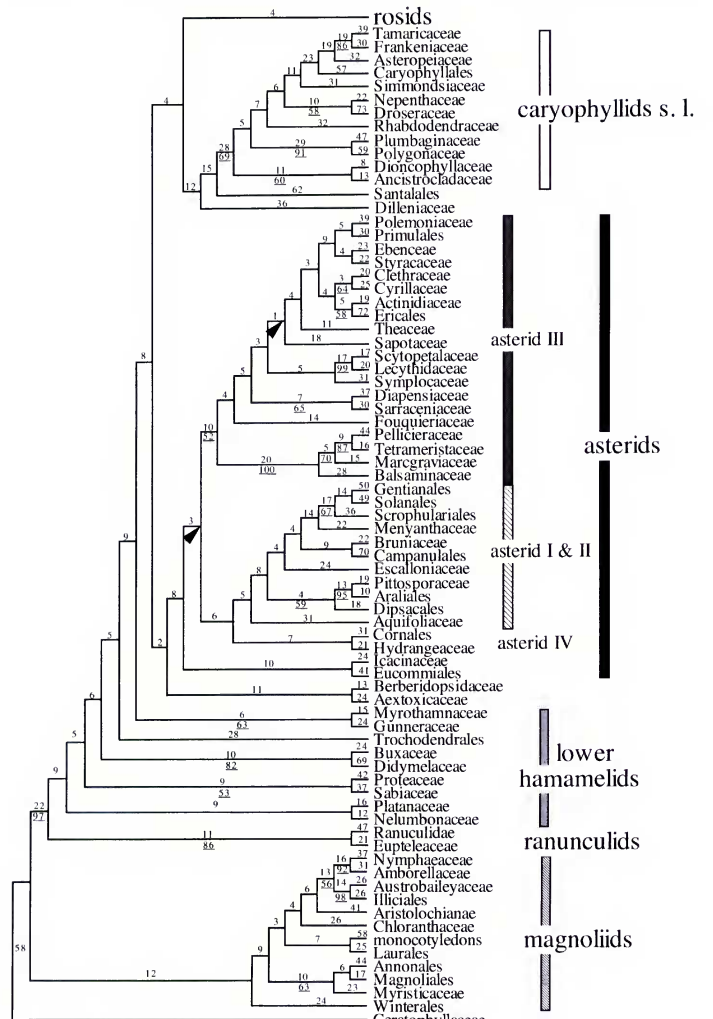
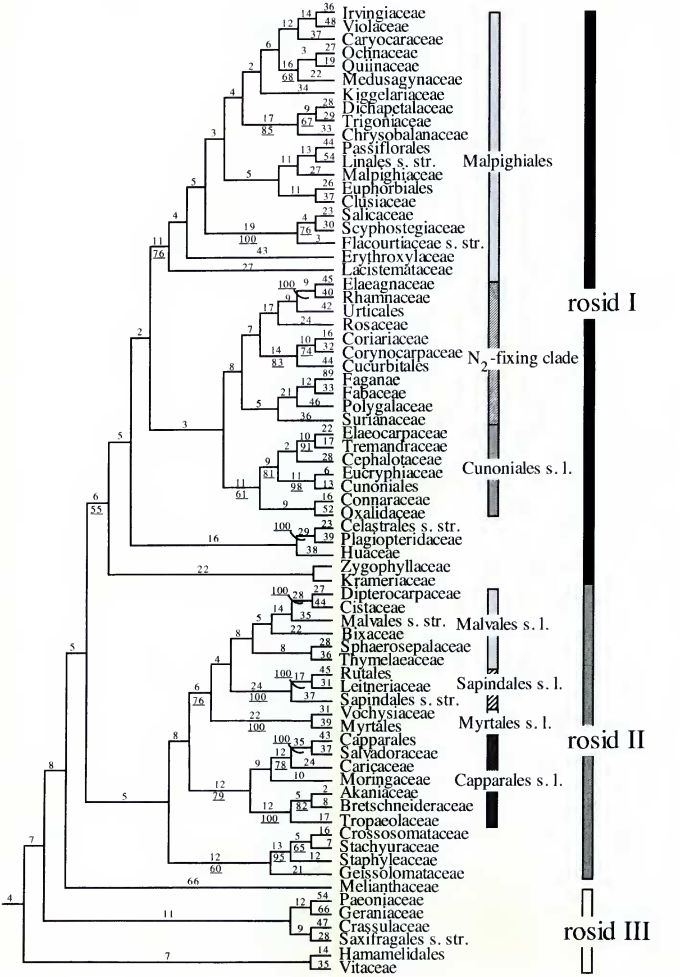
Figure 3. One of nine equally most-parsimonious *rbc*L trees found with successive weighting. Branches not found in all nine trees marked with an arrow. These trees have 6091 steps (Fitch length; i.e., equal weights) with CI = 0.22 and RI = 0.42. Numbers above the branches are the numbers of estimated substitutions (ACCTRAN optimization). Underlined numbers below branches are bootstrap values; branches without an underlined number had bootstrap percentages of less than 50%. —A (left). First-branching portion of the tree, arranged with Ceratophyllaceae as the outgroup. Magnoliids form a clade that is sister to the eudicots. Within eudicots, ranunculids and hamamelids form a grade in which the asterids are sister to the caryophyllids/rosids (for rosids, see Fig. 3B). —B (right). Rosid clade. Note that the glucosinolate and nitrogen-fixing families form clades.


rosids
Tamaricaceae
Frankeniaceae
Asteropeiaceae
Caryophyllales
Simmondsiaceae
Nepenthaceae
Droseraceae
Rhabdodendraceae
Plumbaginaceae
Polygonaceae
Dioncophyllaceae
Ancistrocladaceae
Santalales
Dilleniaceae
caryophyllids s. l.
Polemoniaceae
Primulales
Ebenceae
Styracaceae
Clethraceae
Cyrillaceae
Actinidiaceae
Ericales
Theaceae
Sapotaceae
Scytopetalaceae
Lecythidaceae
Symplocaceae
Diapensiaceae
Sarraceniaceae
Fouquieriaceae
Pellicieraceae
Tetrameristaceae
Marcgraviaceae
Balsaminaceae
Gentianales
Solanales
Scrophulariales
Menyanthaceae
Bruniaceae
Campanulales
Escalloniaceae
Pittosporaceae
Araliales
Dipsacales
Aquifoliaceae
Cornales
Hydrangeaceae
Icacinaceae
Eucommiales
Berberidopsidaceae
Aextoxicaceae
Myrothamnaceae
Gunneraceae
asterid III
asterid I & II
asterid IV
asterids
Trochodendrales
Buxaceae
Didymelaceae
Proteaceae
Sabiaceae
Platanaceae
Nelumbonaceae
lower hamamelids
Ranunculidae
Eupteleaceae
ranunculids
Nymphaeaceae
Amborellaceae
Austrobaileyaceae
Illiciales
Aristolochianae
Chloranthaceae
monocotyledons
Laurales
Annonales
Magnoliales
Myristicaceae
Winterales
magnoliids
Ceratophyllaceae


Irvingiaceae
Violaceae
Caryocaraceae
Ochnaceae
Quiinaceae
Medusagynaceae
Kiggelariaceae
Dichapetalaceae
Trigoniaceae
Chrysobalanaceae
Passiflorales
Linales s. str.
Malpighiaceae
Euphorbiales
Clusiaceae
Salicaceae
Scyphostegiaceae
Flacourtiaceae s. str.
Erythroxylaceae
Lacistemataceae
Malpighiales
Elaeagnaceae
Rhamnaceae
Urticales
Rosaceae
Coriariaceae
Corynocarpaceae
Cucurbitales
Fagaceae
Fabaceae
Polygalaceae
Surianaceae
Elaeocarpaceae
Tremandraceae
Cephalotaceae
Eucryphiaceae
Cunoniales
Connaraceae
Oxalidaceae
Celastrales s. str.
Plagiopteridaceae
Huaceae
Zygophyllaceae
Krameriaceae
Dipterocarpaceae
Cistaceae
Malvales s. str.
Bixaceae
Sphaerosepalaceae
Thymelaeaceae
Rutales
Leitneriaceae
Sapindales s. str.
Vochysiaceae
Myrtales
Capparales
Salvadoraceae
Caricaceae
Moringaceae
Akaniaceae
Bretschneideraceae
Tropaeolaceae
Crossosomataceae
Stachyuraceae
Staphyleaceae
Geissolomataceae
Melianthaceae
Paeoniaceae
Geraniaceae
Crassulaceae
Saxifragales s. str.
Hamamelidales
Vitaceae
N2-fixing clade
Cunoniales s. l.
Malvales s. l.
Sapindales s. l.
Myrtales s. l.
Capparales s. l.
rosid I
rosid II
rosid III

Frankeniaceae (supported at 86%), Asteropeiaceae, Simmondsiaceae, Rhabdodendraceae, and Dioncophyllaceae/Ancistrocladaceae (supported at 60%). Polygonaceae/Plumbaginaceae are strongly supported (91%).

Within the rosid clade (Fig. 3B), the same three major groups as in Chase et al. (1993) were recovered, but only rosid I (55%) has any bootstrap support, and rosid III is a grade (Hamamelidales pair with Vitaceae). The rosid I group includes several newly sequenced families: Caryocaraceae, Clusiaceae, Corynocarpaceae, Dichapetalaceae, Elaeagnaceae, Flacourtiaceae s. str., Kiggelariaceae (the cyanogenic glycoside-producing genera of Flacourtiaceae s.l.), Lacistemataceae, Medusagynaceae, Plagiopteridaceae, Quiinaceae, Salicaceae, Scyphostegiaceae, and Surianaceae. Within the rosid I clade, Plagiopteridaceae are strongly supported (100%) as the sister family of Celastrales s. str. (with more sampling, the former are embedded within the latter; Savolainen & Chase, unpublished). Elaeagnaceae/Rhamnaceae are strongly supported (100%), and Cucurbitales/Corynocarpaceae/Coriariaceae have a moderate bootstrap (83%). The cunonialean clade (61%) comprises Oxalidaceae, Connaraceae, Eucryphiaceae/Cunoniales (98%), Cephalotaceae, and Tremandraceae/Elaeocarpaceae (91%); all but the first two listed have moderate support as a clade (81%).

Within the moderately supported Malpighiales clade (76%), Salicaceae, Scyphostegiaceae, and Flacourtiaceae s. str. are also strongly supported as a clade (100%; with increased sampling the first two families are embedded within the last; Chase et al., 1996). Chrysobalanaceae/Dichapetalaceae/Trigoniaceae have moderate bootstrap support (85%), and Ochnaceae/Quiinaceae/Medusagynaceae have weak support (68%).

The composition of the rosid II group is more or less like that in Chase et al. (1993), except that it includes Myrtales/Vochysiaceae and leaves out Geraniaceae, which appear in rosid III instead. There is no internal support for this clade, but it is recovered in all most-parsimonious trees. Several new families (since Chase et al., 1993) are represented: Bixaceae, Cistaceae, Geissolomataceae, Salvadoraceae, Sphaerosepalaceae, Staphyleaceae, Stachyuraceae, and Thymelaeaceae.

Crossosomataceae/Stachyuraceae/Staphyleaceae/Geissolomataceae is supported at 60% bootstrap level, and within this clade, a subclade of the last three is strongly supported (95%). The mustard-oil clade has moderate support (79%), and within it Tropaeolaceae/Bretschneideraceae/Akaniaceae is strongly supported (100%; the last two at 82%) and Caricaceae/Salvadoraceae/Capparales has moderate bootstraps (78%; the last two at 100%). Vochysiaceae/Myrtales is strongly supported at 100%, and this pair has moderate support (76%) as the sister of Sapindales/Rutales/Leitneriaceae (100%) plus Malvales s.l., comprised of Dipterocarpaceae/Cistaceae (100%), Malvales s. str., Bixaceae, Sphaerosepalaceae, and Thymelaeaceae.

As mentioned above, the rosid III group forms a grade and contains in addition to those families identified in Chase et al. (1993), Geraniaceae and Vitaceae. With more sampling, Geraniaceae are placed near Crossosomataceae. Dilleniaceae, Melianthaceae, and Santalales are not clearly associated with any other lineage.

COMBINED TREES

Analysis of the combined matrix with equal weights produced only 40 trees of 10,183 steps, CI = 0.16, RI = 0.39. As with *rbc*L alone, many characters changed excessively and so we employed successive weighting, which produced a single tree (Fig. 4) with the length of 10,271 Fitch steps, CI = 0.16, and RI = 0.38 (weighted length 631.329, CI = 0.56, RI = 0.63). In general, this topology is like that for *rbc*L, but there are a number of differences. The differences of the combined tree from the non-molecular trees are more substantial, as are the differences between the *rbc*L and the non-molecular trees. The major differences of the combined from the *rbc*L trees are as follows: the magnoliids form a grade rather than a clade; the ranunculids are sister to one of the clades, Platanaceae/Nelumbonaceae, that make up the hamamelid grade; the caryophyllids are sister to a combined rosid/asterid clade, in which these are monophyletic sister groups; Malvales s. str. are the sister to Bixaceae, Cistaceae, and Dipterocarpaceae in the combined tree, whereas they are placed between Bixaceae and Cistaceae/Dipterocarpaceae in the *rbc*L trees; the Bixales group with the taxa having a bixoid chalaza in their seeds (Nandi, 1998a; 159) thus appears as monophyletic in our combined tree (Sarcolaenaceae, for which no *rbc*L sequence was available, do have a bixoid chalaza; this character was found too late to be included in the matrix; if this character-state could be coded, Sarcolaenaceae would probably appear in the Bixales group as well); Fabaceae are placed outside the nitrogen-fixing clade in the combined tree; Clusiaceae are placed in a clade with Caryocaraceae, Elatinaceae (only non-molecular data), and Bonnetiaceae (only non-molecular data) in the combined tree, whereas they appear as the sister group of Euphorbiales in

the *rbc*L trees; Violaceae are found in a group that is sister to a large clade containing, e.g., Flacourtiaceae s. str. and Euphorbiales, whereas they are placed differently in the *rbc*L trees; Kiggelariaceae are sister to Flacourtiaceae s. str., Scyphostegiaceae, and Salicaceae in the combined tree, whereas they are more distant from Flacourtiaceae s. str. in the *rbc*L trees.

The addition of the non-molecular data to the *rbc*L matrix greatly reduced the number of trees obtained; in the case of the Fitch analysis it dropped from more than 5000 (at which point the memory was exhausted) to only 40, and in the weighted analysis from nine to only one. If there were agreement between patterns in the molecular and non-molecular data, then an effect of increased support might be observed in the combined analysis. This is partly the case, but the amount of missing data in the non-molecular analysis makes this assessment difficult; there are many exceptions noticed by comparing Figures 3 and 4. For example, support for an expanded Nymphaeales (including Amborellaceae, Austrobaileyaceae, and Illiciales) decreases slightly (from 56% to 53%), but the support for the two pairs, Nymphaeaceae/Amborellaceae and Illiciales/Austrobaileyaceae, decreases markedly, from 92% and 98% to 86% and 75%, respectively. Citing all such cases is not a worthwhile endeavor at this stage of investigation. At the least, it can be stated that the addition of the non-molecular data does not drastically alter the pattern obtained with *rbc*L alone, nor does it greatly decrease bootstrap support.

TAXA IN THE *rbc*L TREES FOR WHICH INSUFFICIENT NON-MOLECULAR DATA ARE AVAILABLE

A number of small families have been included in the non-molecular matrix, but little information is available for them. The presence of such taxa can destabilize results and produce lower levels of internal support. Most of these taxa received strong support for placement in the *rbc*L trees, and they seem relatively securely placed in the combined tree. We point out these taxa here to draw attention to them: Tetrameristaceae and Pellicieraceae are found near Marcgraviaceae in the *rbc*L and combined trees (Figs. 3A, 4A) and are also sister groups tending to be placed in asterids in the non-molecular trees (Fig. 2A); Corynocarpaceae falls in the clade formed by Coriariaceae and Cucurbitales (including Datiscaceae and Begoniaceae) in the *rbc*L and combined trees; Leitneriaceae have a stable position near Rutales/Sapindales; Huaceae are placed near Celastrales s. str.; and Lacistemataceae and Scyphostegiaceae are found near Flacourtiaceae s. str.

Discussion

Certain caveats must be proffered before further consideration of the results of these analyses. To overcome the disadvantages of high taxon number and large amounts of missing data (which always slows the process of finding shorter trees; pers. obs.), we regrouped the taxa into three subgroups (Search III). These corresponded to what we presumed were magnoliids, lower eudicots, and caryophyllids (group I), rosids (group II), and asterids (group III). This led to the advantage of shorter and more thorough computation and ultimately yielded trees up to six steps shorter than those found with the other two search strategies. This method is somewhat biased in presuming three major groups, but the final unconstrained swapping and reweighting procedures should compensate for the biases thus introduced. With an RI of 0.41, this matrix is highly likely to be subject to islands (Maddison, 1991), and this appeared to cause problems for standard types of search strategies. This is likely true also for the *rbc*L and combined matrices, although these were clearly more consistent in finding reasonably similar tree lengths in each of the random replicates of taxon-entry order.

The methods used for coding of the non-molecular data can be improved. Assessments of character polarity before analysis are assumption-laden. Coding only a single character that is assumed to be the plesiomorphic state for cases in which polymorphisms occur could result in spurious place-

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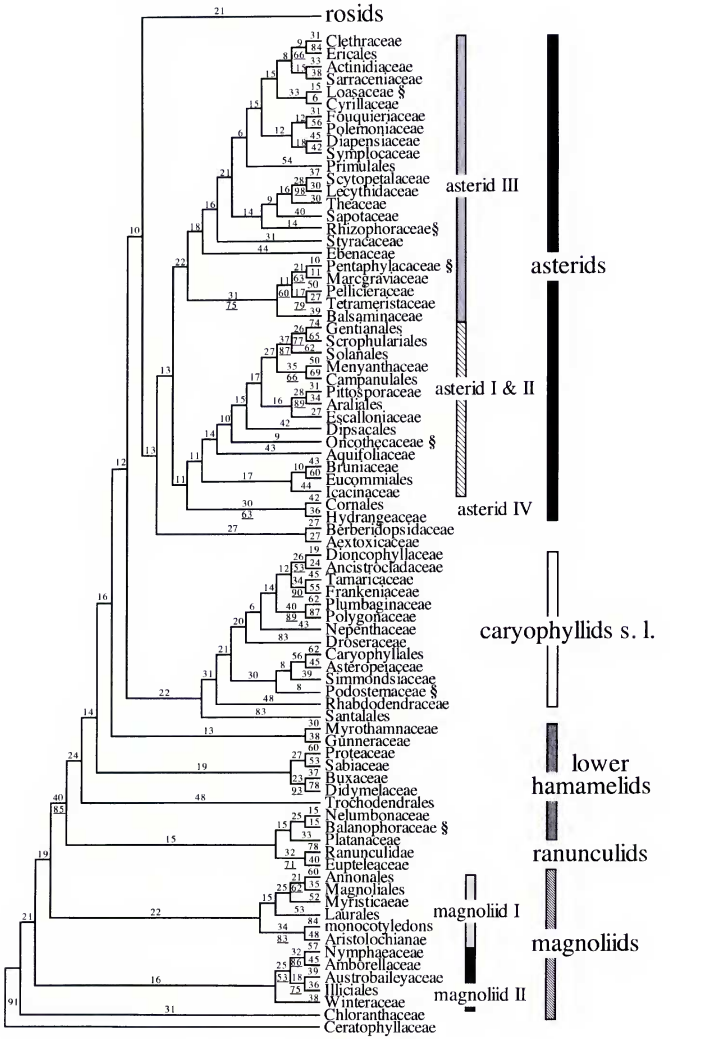
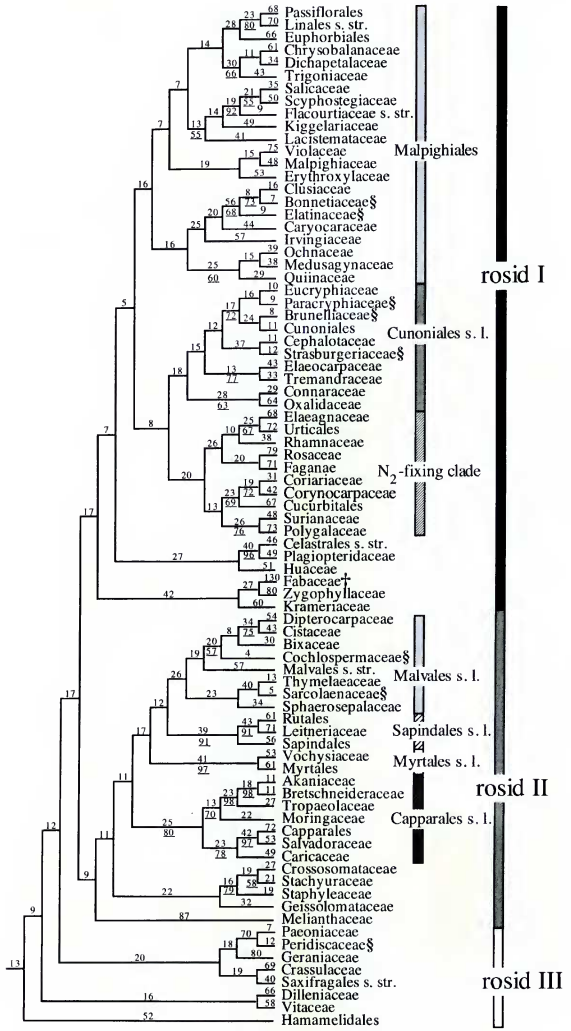
Figure 4. The single most-parsimonious combined tree found with successive weighting. The tree has 10,271 steps (Fitch length; i.e., equal weights) with CI = 0.16 and RI = 0.38. Numbers above the branches are the numbers of estimated changes (ACCTRAN optimization). Underlined numbers below branches are bootstrap values; branches without an underlined number had bootstrap percentages of less than 50%. —A (left). First-branching portion of the tree, arranged with Ceratophyllaceae as the outgroup. Magnoliids form a grade composed of two major subclades (magnolid I and II) with the former sister to the eudicots. Within eudicots, ranunculids and hamamelids form a grade. The caryophyllids are sister to the asterids/rosids (for rosids, see Fig. 4B). —B (right). Rosid clade. Note that the glucosinolate and nitrogen-fixing families form clades. *Taxa for which *rbc*L sequences were unavailable. †Nitrogen-fixing family outside the main nitrogen-fixing clade (Fabaceae).


rosids
Clethraceae
Ericales
Actinidiaceae
Sarraceniaceae
Loasaceae §
Cyrillaceae
Fouquieriaceae
Polemoniaceae
Diapensiaceae
Symplocaceae
Primulales
Scytopetalaceae
Lecythidaceae
Theaceae
Sapotaceae
Rhizophoraceae§
Styracaceae
Ebenaceae
Pentaphylacaceae §
Marcgraviaceae
Pelliciaceae
Tetrameristaceae
Balsaminaceae
Gentianales
Scrophulariales
Solanales
Menyanthaceae
Campanulales
Pittosporaceae
Araliales
Escalloniaceae
Dipsacales
Oncothecaceae §
Aquifoliaceae
Bruniaceae
Eucommiales
Icacinaceae
Cornales
Hydrangeaceae
Berberidopsidaceae
Aextoxicaceae
Dioncophyllaceae
Ancistrocladaceae
Tamaricaceae
Frankeniaceae
Plumbaginaceae
Polygonaceae
Nepenthaceae
Droseraceae
Caryophyllales
Asteropeiaceae
Simmondsiaceae
Podostemaceae §
Rhabdodendraceae
Santalales
Myrothamnaceae
Gunneraceae
Proteaceae
Sabiaceae
Buxaceae
Didymelaceae
Trochodendrales
Nelumbonaceae
Balanophoraceae §
Platanaceae
Ranunculidae
Eupteleaceae
Annonales
Magnoliales
Myristicaceae
Laurales
monocotyledons
Aristolochianae
Nymphaeaceae
Amborellaceae
Austrobaileyaceae
Illiciales
Winteraceae
Chloranthaceae
Ceratophyllaceae
asterid III
asterid I & II
asterid IV
magnoliid I
magnoliid II
asterids
caryophyllids s. l.
lower hamamelids
ranunculids
magnoliids


Passiflorales
Linales s. str.
Euphorbiales
Chrysobalanaceae
Dichapetalaceae
Trigoniaceae
Salicaceae
Scyphostegiaceae
Flacourtiaceae s. str.
Kiggelariaceae
Lacistemataceae
Violaceae
Malpighiales
Malpighiaceae
Erythroxylaceae
Clusiaceae
Bonnetiaceae§
Elatinaceae§
Caryocaraceae
Irvingiaceae
Ochnaceae
Medusagynaceae
Quiinaceae
rosid I
Eucryphiaceae
Paracryphiaceae§
Brunelliaceae§
Cunoniales
Cunoniales s. l.
Cephalotaceae
Strasburgeriaceae§
Elaeocarpaceae
Tremandraceae
Connaraceae
Oxalidaceae
Elaeagnaceae
Urticales
Rhamnaceae
Rosaceae
Faganae
N2-fixing clade
Coriariaceae
Corynocarpaceae
Cucurbitales
Surianaceae
Polygalaceae
Celastrales s. str.
Plagiopteridaceae
Huaceae
Fabaceae†
Zygophyllaceae
Krameriaceae
Dipterocarpaceae
Cistaceae
Bixaceae
Cochlospermaceae§
Malvales s. str.
Malvales s. l.
Thymelaeaceae
Sarcolaenaceae§
Sphaerosepalaceae
Rutales
Leitneriaceae
Sapindales
Sapindales s. l.
Vochysiaceae
Myrtales
Myrtales s. l.
rosid II
Akaniaceae
Bretschneideraceae
Tropaeolaceae
Moringaceae
Capparales
Capparales s. l.
Salvadoraceae
Caricaceae
Crossosomataceae
Stachyuraceae
Staphyleaceae
Geissolomataceae
Melianthaceae
Paeoniaceae
Peridiscaceae§
Geraniaceae
Crassulaceae
Saxifragales s. str.
rosid III
Dilleniaceae
Vitaceae
Hamamelidales

ments of some taxa. An example of an assumed apomorphy can be seen in the results for Lilianae in Chase et al. (1995), in which the combined *rbc*L and morphology trees indicated that an inferior ovary was the plesiomorphic condition. This is the opposite conclusion one would reach based upon generalized character trends in angiosperms, and such conclusions could result in spurious assessments of relationships. Moreover, coding terminals as polymorphic can also produce erroneous topologies (Nixon & Davis, 1991). Adding terminals would be a solution, but it would involve unmanageable matrix dimensions and the need for more specific data on variation within larger clades. For example, if a taxon B is deeply nested within a large taxon A, it would be difficult to detect this relationship with our data. Taxon B would most likely attach to a subgroup of taxon A (which in our matrix may be absent). This would mean that large taxa have to be split up. An example of this problem is our use of Rutales, Sapindales, and Leitneriaceae. With more sampling within the two orders (Gadek et al., 1996), Leitneriaceae is embedded within Simaroubaceae of Sapindales. In our trees, it appears as sister to Sapindales. Despite these caveats, the approach used here is made stronger by the inclusion of many more characters than taxa. As long as most characters are accurately scored, the general results should contain useful and new information, and the "phylogenetic signal" should not be overly distorted.

The non-molecular matrix often deals with large taxonomic units composed of many families. The results are thus meaningful only if these taxa are monophyletic. We used higher-order taxa when the results of Chase et al. (1993) and many published studies (Appendix 6) coincided with the traditonal circumscription of these groups. In the *rbc*L and combined analyses, these groups were represented by only a single sequence of a representative species. The effects of using exemplars is discussed in Sytsma and Baum (1996), but the results do not differ significantly from other *rbc*L studies using more than single representatives.

A different approach would have been to use species as terminals, preferably the same species as covered by the *rbc*L database. This approach, however, would have the disadvantage that not all character fields would be investigated for the species or even the genus in question. Moreover, it seems most likely that the coverage of all angiosperms with exemplar species would require a sample of more terminal taxa than in this study. This again would necessitate more phylogenetically informative characters. This species-terminal approach, at the present time, is impractical and could not be effected; there simply are not enough species studied for all these characters.

We intend this study to be an example of the direction that we think phylogenetic studies should be taking. We will be most gratified if other researchers take our matrices and improve upon them. The literature is voluminous. We have surely missed a number of papers, but these matrices are now there to be completed. The gaps will be obvious to those who are interested. The missing cells need to be filled in, and we can see that if they are, there is hope for improvement. For those taxa on which we have focused most and incorporated more of the relevant literature (e.g., Malvales s.l.), the non-molecular (Fig. 2B), the molecular (Fig. 3B), and combined trees (Fig. 4B) are all highly congruent. The non-molecular results for Cochlospermaceae, Bixaceae, Cistaceae, Dipterocarpaceae, and Sarcolaenaceae also demonstrate that the search for characters has to consider a wide array of subject areas.

The final caveat concerns the use of successive weighting to "improve" the matrices (Farris, 1969). Some readers will wonder how this procedure has "distorted" the results produced by equal weighting, the results of which we have not shown. All data sets contain characters that are excessively "noisy," and these can be detected by an examination of their consistency on any of the trees (Fig. 1). This is evidence that, although these characters may be useful at some hierarchical level, they are not useful at the broad scale being studied here. A priori one cannot and should not make this sort of decision; it is simply too assumption-laden. When the initial results from an analysis indicate that certain characters are relatively more inconsistent than others, then the effects of the former should be lessened and those of the latter enhanced (i.e., made more consistent). The effect of successive weighting is never vastly different from that of equal weighting; in the great majority of cases, successive weighting merely identifies a subset of the trees found with equal weights as optimal (i.e., those that favor the more consistent characters). This is not the case with any of the trees found here, but both the *rbc*L and combined results have nearly the same Fitch length as the most-parsimonious Fitch tree (the weighted trees are only 0.56% and 0.86% longer than the Fitch trees for *rbc*L alone and the combined matrices, respectively; the CI and RI for the Fitch and weighted trees are nearly identical and only differ at the third decimal point levels, CI = 0.217 versus 0.215 and RI = 0.428 versus 0.424 for *rbc*L, and CI = 0.160 versus 0.159 and RI =

0.390 versus 0.384 for the combined analysis). We attempted to use successive weighting on the non-molecular data, but, like the search protocol itself, this procedure would have occupied many months of computer time and was therefore abandoned.

(A) TREES AND GENERAL PATTERNS

No previous cladistic analysis of the angiosperms has used as many higher-level taxa as this, including Chase et al. (1993) and Soltis et al. (1997b), which both used more species but fewer families. Of course, many of the families are subsumed in these trees by higher-order taxa (i.e., monocotyledons, Faganae, Urticales). This process of selecting terminals did not have a great effect on topology for the *rbc*L-only analysis, which deviates only slightly from that seen in Chase et al. (1993), and our results also do not differ drastically from those produced by 18S rDNA either (Soltis et al., 1997b). Several more divergent families are differently placed, which could be due to the overall sparser sampling permitting branch attractions to occur. These families (relative to Chase et al., 1993) are: Geraniaceae, in rosid II near *Crossosoma* before, here in rosid III (Fig. 3B); Vitaceae, in an isolated position with Dilleniaceae before, here with Hamamelidales; Krameriaceae/Zygophyllaceae, near Rosaceae in rosid I before, here in an isolated position as sister to the rosid I clade; and Fabaceae, which in the *rbc*L trees falls into the nitrogen-fixing clade (Fig. 3B) but in the combined tree is sister to Zygophyllaceae/Krameriaceae.

Several taxa occupy isolated positions in the *rbc*L and combined trees, and these would appear to be critical for understanding the patterns observed in the largest clades (i.e., rosids, asterids, and caryophyllids). These include Aextoxicaceae, Berberidopsidaceae, Dilleniaceae, Gunneraceae, Myrothamnaceae, Vitaceae, and Santalales. These taxa have shifted positions in every published large *rbc*L analysis, but they always come out as the sister taxa of the largest clades of eudicots. Within the asterids, Aquifoliaceae, Eucommiales, and Icacinaceae perform similarly; among rosids the Celastrales s. str./Plagiopteridaceae, Huaceae, Krameriaceae/Zygophyllaceae, Melianthaceae, and Crossosomataceae/Stachyuraceae/Staphyleaceae/Geissolomataceae clades are likewise unstable. Their positions in the non-molecular trees are generally different from their positions in the *rbc*L and combined trees. Aextoxicaceae, Berberidopsidaceae, Dilleniaceae, Gunneraceae, Myrothamnaceae, Vitaceae, and Santalales, those taxa that fall as sister groups of the asterids, caryophyllids, and rosids in Figures 3 and 4, are embedded among the magnoliids or included in the rosid groups that fall apart from the main rosid clade in the non-molecular trees (Fig. 2A). These taxa have a large number of plesiomorphic traits. For example, *Berberidopsis* (Berberidopsidaceae) has an undifferentiated perianth, plesiomorphic wood (presence of mostly solitary vessels with scalariform perforation plates and opposite side-wall pitting, absence of septate fibers), and tricolpate pollen (Miller, 1975; Lemke, 1988).

The *rbc*L data contain significantly greater phylogenetic information than the non-molecular data in this broad study (e.g., they delimit more groups with greater levels of internal support). In part, this must be ascribed to the structure of the non-molecular matrix, containing many empty cells and also a larger number of polymorphisms. Moreover, it has become obvious that all larger clades of angiosperms can only be characterized by few non-molecular traits (see part b of Discussion). This results in a matrix that seems to yield only slightly longer trees using standard methods (i.e., no compartmentalization). In phylogenetics, it has been underestimated that the more "signal" (i.e., the less randomness) is contained in a data matrix, the easier it is to find optimal trees. The 1993 *rbc*L tree was obtained in a relatively short search (Chase et al., 1993); trees only five steps shorter were found by Rice et al. (1995) after many more months of search on more than one computer. The only differences between these minimally shorter trees and the trees found in 1993 concern groupings that are weakly supported regardless of their positions. Nothing more of significance has been obtained except a huge outlay of computing time and personal effort; the 1993 tree contained all of the strongly supported groupings, and represents well the phylogenetic signal present in *rbc*L data. It should be accepted that with large searches for which exact solutions are impossible (such as this and the other large angiosperm matrices) excessive swapping over several months is not reasonable; effort is better spent in finding additional data. When all groups are strongly supported, then finding the optimal solution will be easy and the trees accurate (Soltis et al., in press). Even after many additional months of search on the 1993 *rbc*L matrix, we cannot say that anything new was learned. The most that was achieved was the observation that many groups, especially those with long branches, were unstable. Of course, we performed bootstrap analyses here, and this makes the general weakness of the *rbc*L tree evident. Unpublished analyses of *atp*B for nearly 300 seed plants take even less time than *rbc*L and contain even more groups with strong sup-

port. Soltis et al. (1997b) presented 18S rDNA data for 232 seed plants. The authors reported that more time is required for 18S than for *rbc*L alone or *rbc*L-18S combined searches, and again the major problem with large data sets is not just their size, but also the degree of randomness and missing cells that they contain. The large number of question marks and lack of support in the non-molecular matrix are serious obstacles to rapid search. Likewise, they do not permit the use of the jackknife (J. Farris, pers. comm.), which is a fast and accurate method of finding groups with strong internal support, regardless of the size of the matrix (Farris et al., 1997).

Some authors have suggested that hybridization or other forms of horizontal gene transfer could have a major effect on higher level studies within the angiosperms and could be expected to create conflicts between data categories (Syvanen et al., 1989; Syvanen, 1994). Others did not give hybridization a major role at higher levels (Chase et al., 1993). We do not deny that high levels of parallelisms exist among angiosperms, but we find the explanation of widespread horizontal gene transfer as the cause (Syvanen, 1994) unappealing and not conducive to further investigation. Studies of nuclear 18S rDNA (Soltis et al., 1997b) and plastid *atp*B (Savolainen et al., 1996) find results highly congruent with those of *rbc*L. In particular, the congruent topologies found with plastid genome sequences (*rbc*L and *atp*B) as well as with nuclear genome sequences (18s rDNA) argue against hybridization being a major problem in higher level plant systematics. Reticulate evolution, dating to a time when hybridization was still possible between now distant lines, appears to have only minor effects on macrosystematic patterns (for discussion of effects leading to parallelisms, see also Kubitzki et al., 1991).

(B) NON-MOLECULAR CHARACTERS OF TAXON GROUPS DISCUSSED ON THE BASIS OF THE COMBINED DATA TREE (FIG. 4 A, B)

We argue that the trees with the greatest underlying data are the most appropriate to discuss; thus, unless specifically stated, we will discuss only the combined tree from Figure 4. We focus on a series of characters that appear to contribute to the topology obtained in the combined tree. This is not meant to be an exhaustive examination of these topics. We intend instead to illustrate some of the trends in the non-molecular data that agree with the distribution of variation in the *rbc*L matrix. Characters described are synapomorphies as yielded by MacClade 3.04 on the combined tree, unless stated otherwise. Other characters that are widely represented within a clade may represent synapomorphies if the topologies are only slightly rearranged; since many of these branches are weakly supported, discussing these characters as either synapomorphies or plesiomorphies seems premature and potentially misleading. Therefore we discuss many characters as simply being widespread or frequent within clades; many of these will eventually be demonstrated to be synapomorphies. Due to the large number of missing cells and low levels of internal support with present data, it seems most prudent to consider only their relative frequencies or tendencies of occurrence rather than to frame this discussion as an investigation of synapomorphies.

Magnoliidae. The strict dichotomy of the leaf parts in *Ceratophyllum* is unusual in angiosperms, even if compared with other water plants showing the *Hippuris* syndrome of leaf architecture (cf. also Cook, 1978; Rutishauser & Sattler, 1987). The inflorescence is a spike with the flowers frequently arranged in two orthostichies (Raynal-Roques, 1981). This inflorescence type shows some similarities to the decussate spikes in *Chloranthus* and could reflect an old pattern. Also the flowers in *Ceratophyllum* are unisexual (Endress, 1994b), and this could be plesiomorphic for angiosperms or apomorphic as a result of adaptation to an aquatic autecology.

Chloranthaceae occupy an isolated and perhaps early-diverging position (see also Nixon et al., 1994). This is concordant with the fact that the oldest fossils known at present that are clearly attributable to angiosperms are Chloranthaceae-like. Chloranthoid pollen was described from the Valanginian of Israel (Brenner, 1996). *Hedyosmum*-like flowers are known from the Valanginian or Hauterivian of Portugal (Friis et al., 1994; Crane et al., 1995; E. M. Friis, pers. comm.) and are thus even older than the *Ceratophyllum*-like horned fruits found from an Aptian locality (Dilcher, 1989). The fact that distinct Aptian fossil material has been found that appears to combine characters of Chloranthaceae, Piperales, and Circaeasteraceae (Ranunculidae; Crane et al., 1995) indicates that early angiosperms exhibited a suite of traits that are now only known to occur individually within distinct terminal clades of extant angiosperms. The decussate arrangement of the flowers in spicate inflorescences in *Chloranthus* and the Late Cretaceous *Chloranthistemon* (Endress, 1987; Eklund et al., 1997) is paralleled by the decussate inflorescences

of *Ephedra* (Hufford, 1996). The comparison of branched male structures in Gnetales and Chloranthaceae is problematical because of unclear homologies (Endress, 1987; Friis & Endress, 1990; Doyle, 1994, 1996). For comparison of Chloranthaceae with Gnetales see also Taylor and Hickey (1996) and critical discussion by Doyle (1996) and Endress and Igersheim (1997). Also the highest diversity of pollen aperture types within an angiosperm family seems to occur in Chloranthaceae (not expressed in the characters used for this analysis; see, e.g., Erdtman, 1952). Sesquiterpenes, as γ-elemene, can serve to indicate relationships of Chloranthaceae to other angiosperm families. At present, γ-elemene is known only from Chloranthaceae, Piperaceae, and Aristolochiaceae (Hegnauer, 1962–1994). The germacrene acoragermacrene occurs only in Chloranthaceae and monocots (Hegnauer, 1962–1994). These two compounds seem to indicate an evolutionary relationship of Chloranthaceae to Aristolochianae–monocots or are a relict of previously more widespread traits.

Amborella also occurs in an isolated position in our non-molecular trees (Fig. 2A). *Amborella* was found as the sister group to the rest of angiosperms in a subset of the 18S rDNA trees (Soltis et al., 1997b), but in a clade supported by the jackknife along with Illiciales, Austrobaileyaceae, and Nymphaeales in the combined analysis of *rbc*L and 18S in Soltis et al. (1997a). Probably ancestral or erratic characters of *Amborella* include the presence of S-type plastids in the sieve-tubes (107), uniaperturate in addition to inaperturate pollen grains (129; Sampson, 1993), minute embryos (163), scanty wood parenchyma (174), no fibers (not coded), tracheids (177), wood rays of Kribs heterogeneous type I (179), circular tracheid side-wall pitting (similar to some Gnetales; 184), no vessels (not coded; probably plesiomorphic), no discontinuous calyx-corolla transgression (210), practically orthotropous ovules (246), and stipitate fruits (239) (Metcalfe & Chalk, 1950; Behnke, 1981; Cronquist, 1981; Takahashi, 1985; Carlquist, 1988a; Endress, 1994c). Brenner (1990, 1996) reported that angiospermous, inaperturate pollen grains, which may have evolved into a *Clavatipollenites* pollen-type, are present in the Valanginian and Hauterivian of Israel. Judging from these paleobotanical finds, one may take into consideration whether the inaperturate pollen grains found in *Ceratophyllum, Ascarina* (Todzia, 1993), *Amborella, Trimenia papuana* (see Sampson & Endress, 1984), and many Laurales (Gomortegaceae, Hernandiaceae, Lauraceae, Monimiaceae except Atherospermatoideae) are reductions or represent an old, conserved, character-state. Neglect of the presence of inaperturate pollen in the above-mentioned magnoliid taxa based on the assumption that the inaperturate condition does not represent the basal pollen type could result in different topologies at the base of the tree.

All taxa of magnoliids and early-branching eudicots included in this analysis have ovary-to-carpel length ratios greater than 1:2 (i.e., with short or absent styles; 236). The formation of long styles in relation to the whole carpel thus seems to be an apomorphic tendency in basal angiosperms. A mesotesta (middle layer of outer integument in the seed; 154) with sclerified cells is present in many magnoliids: Chloranthaceae (*Chloranthus* spp.), Nymphaeaceae, Austrobaileyaceae, Illiciales, Aristolochianae (*Aristolochia* spp.), Myristicaceae (*Horsfieldia, Myristica*), Annonales, Magnoliales (Corner, 1976; Endress, 1980; Takhtajan, 1988). A mechanical layer in the mesotesta is also found in some early-branching eudicots (Eupteleaceae; Buxaceae: *Sarcococca*; and Hamamelidaceae; Corner, 1976).

The clade formed by Laurales, Aristolochianae, monocots, Myristicaceae, Annonales, and Magnoliales (magnoliid I clade; Fig. 4A) shows a frequent occurrence of the phenylpropane asarone (41). Asarone is known from Lauraceae (*Sassafras*), Piperaceae (Piper), Aristolochiaceae (*Asarum*), Annonaceae, and Magnoliaceae (*Magnolia*) (Gildemeister & Hoffmann, 1956; Hegnauer, 1962–1994; Sethi et al., 1976; Keller, 1982). Outside of this clade Hegnauer (1962–1994) cited only three families of angiosperms that produce asarone. The same clade contains the only plant taxa that Hegnauer (1962–1994) and Harborne and Baxter (1993) found to produce the lignans galbacin (57) and veraguensin (59). The neolignan licarin (58), though described from *Krameria* (Dominguez et al., 1992), is also predominantly found in this magnoliid I clade (Gottlieb et al., 1988, stated that neolignans have their center of diversification in the magnolialean families). Galbacin, a tetrahydrofuranoid lignanoid, occurs in Lauraceae (*Persea*), Aristolochiaceae (*Aristolochia*), Myristicaceae (*Knema, Virola*), and Himantandraceae (*Galbulimima*) (Hegnauer, 1962–1994; Harborne & Baxter, 1993). Veraguensin, also a tetrahydrofuranoid lignanoid, is known to occur in Trimeniaceae (*Trimenia*), Lauraceae (*Ocotea*), Saururaceae (*Saururus*), Myristicaceae (*Virola*), and Magnoliaceae (*Magnolia*) (Harborne & Baxter, 1993). Licarin has been found in Lauraceae (*Licaria*), Aristolochiaceae (*Aristolochia*), Myristicaceae (*Myristica*), and Magnoliaceae (Hegnauer,

1962–1994; Ionescu et al., 1977; Le Quesne et al., 1980; Harborne & Baxter, 1993).

The alkaloid liriodenine (83) is known only in the magnoliid I clade, as well as in Ranunculidae and Nelumbonaceae; the last-mentioned taxa fall into the sister group of the remaining eudicots. As with two of the three lignanoids mentioned above, liriodenine is not known from any families outside of these clades, most significantly not from the magnoliid subclade containing Winterales, Nymphaeaceae, Amborellaceae, Austrobaileyaceae, and Illiciales (Hegnauer, 1962–1994; Harborne & Baxter, 1993), hereafter the magnoliid II clade (Fig. 4A). The magnoliid I clade further has sieve-tube plastids of the P-type (107) in a majority of families (Behnke, 1981), whereas all members of the magnoliid II clade except Canellaceae (here in Winterales) have S-type plastids. Aristolochianae and monocots are further linked by the common presence of crystal sand (in Piperaceae, Metcalfe & Chalk, 1989, and Araceae, but not in *Acorus*, Solereder & Meyer, 1928; Franceschi & Horner, 1980; Seubert, 1993; 115), of a dispersed vascular system (in Piperaceae and monocots, but not in Saururaceae; 167), and of frequent trimery in perianth (212–214), androecium (221), and gynoecium (233–235). Aristolochianae and monocots also cluster on the basis of the widespread occurrence of two stamen whorls (not coded). More similarities, perhaps as the result of common ancestry, are enumerated by Burger (1977) and Dahlgren and Clifford (1982). All magnoliid I families except monocotyledons/Aristolochianae share a stratified phloem (169) and wedge-shaped phloem rays (Metcalfe & Chalk, 1950; Cronquist, 1981; Carlquist, 1988a; 170).

Both the non-molecular and the combined trees show Chloranthaceae as an isolated family apart from the main magnoliid clades. Also equally isolated in all trees are Amborellaceae, Austrobaileyaceae, and Illiciales (magnoliid II clade), separated from the more typical magnoliid I clade, in which the monocots are sister to Piperales/Lactoridaceae/Aristolochianae (Fig. 4A).

Eudicots. Eudicots are held together by their triaperturate pollen grains (129), which most likely evolved in parallel in Illiciales (Erdtman, 1952; Doyle et al., 1990; Qiu et al., 1993).

Many early-branching eudicots have representatives with tricolpate pollen grains; these are cited here, as in Chase et al. (1993), as the ranunculids and lower hamamelids (the latter a grade composed of several small clades). These taxa are nearly all relatively small and could be considered remnants of previously more widespread and numerous archaic lineages. In our scheme, these lineages would include Berberidopsidaceae, Nelumbonaceae, Platanaceae, Ranunculidae, Proteaceae, Gunneraceae, Myrothamnaceae, and Trochodendrales. Vitaceae and Aextoxicaceae appear to be related also to these, but exhibit some more advanced characters, such as tricolporate pollen, which is more predominant in derived eudicot lineages (see, e.g., Erdtman, 1952). In *Nelumbo*, both tricolpate and monosulcate pollen are reported (Kuprianova, 1979; Blackmore et al., 1995; coded only as tricolpate in the matrix because we became aware of the occurrence of monosulcate pollen in *Nelumbo* only after analysis). The sister group of the rest of eudicots consists of Nelumbonaceae, Platanaceae, Eupteleaceae, and Ranunculidae. A number of these families have some members with palmately veined leaves or leaves with no dominant single primary vein (i.e., Menispermaceae, Lardizabalaceae, Circaeasteraceae, Ranunculaceae, Berberidaceae, Nelumbonaceae, and Platanaceae; 198). The leaves of *Kingdonia* and *Circaeaster* are particularly interesting for their dichotomously branching venation, which is rare in angiosperms (for the conditions in *Kingdonia*, see Foster & Arnott, 1960; morphogenetic interpretations by Hagemann, 1970, and Hagemann & Gleissberg, 1996). Foster and Arnott (1960) hypothesized that the dichotomous venation pattern in *Kingdonia* represents an ancestral character-state. Imprint leaf fossils from the Early Cretaceous of Madagascar have been found that show characters similar to extant *Circaeaster* (O. Appert, pers. comm.). Circaeasteraceae and Kingdoniaceae were placed in the ranunculalean clade by Oxelman and Lidén (1995; here including *Trochodendron*) based on an analysis of 28S rRNA. They were also given family rank (as members of a distinct order in the Ranunculidae) by Takhtajan (1997).

Proteaceae and Sabiaceae are linked by the common presence of wedge-shaped phloem rays (Metcalfe & Chalk, 1950; 170) and of a nectary disk (Haber, 1959, 1961, 1966; van Beusekom, 1971; 231), a rare character in the early-branching angiosperms. Buxaceae and Didymelaceae share a simple, bract-like perianth (possibly plesiomorphic; 209) and encyclocytic stomata (195), the latter a rare character-state present in only eleven taxa of our analysis (see also Metcalfe & Chalk, 1950, 1988, 1989). Aextoxicaceae and Berberidopsidaceae are also linked by this same character (Cronquist, 1981; Baas, 1984).

Ellagic acid is not only absent from the magnoliids, with the exception of Nymphaeales (Amborellaceae have not been sampled), but also from the

first-branching eudicots, Ranunculidae, Eupteleaceae, Platanaceae, Nelumbonaceae, Proteaceae, Sabiaceae, Buxaceae, and Trochodendrales. Gallic acid (70) shows a similar distribution (Hegnauer, 1962–1994; Gibbs, 1974).

The morphological data set does not establish the sister-group position of Ranunculidae to the remaining eudicots but places them nested in the magnoliid I clade (Fig. 2A). Perhaps a better knowledge of the biochemistry of some basal eudicots (Eupteleaceae, Platanaceae, Sabiaceae, Didymelaceae) would cause a somewhat modified placement of Ranunculidae. The non-molecular trees also do not consistently separate *Nelumbo* from magnoliid I (Fig. 2A). In all trees *Trochodendron*, *Tetracentron*, Proteaceae, Sabiaceae, Buxaceae, and Didymelaceae are in an isolated position (cf. also Drinnan et al., 1994). *Berberidopsis*, a ditypic Australian–Chilean disjunct genus, shows no close relationships to Flacourtiaceae in either data set. A distinct position of *Berberidopsis* within the core-Flacourtiaceae s.l. was already indicated by Keating (1975) on the basis of pollen morphology and by Miller (1975) on the basis of wood anatomy. The *rbc*L and combined analyses place Berberidopsidaceae and Aextoxicaceae (also from Chile) as sister to the asterids (Figs. 3A, 4A), and the non-molecular analysis places them with the magnoliid I clade (Fig. 2A).

Dilleniaceae and Vitaceae have never been considered closely related, but they share oxalate raphides (Metcalfe & Chalk, 1950; 113), an endotesta containing radially elongate cells (156), and a tracheidal exotegmen (Corner, 1976; 157).

Caryophyllidae s.l. Albert et al. (1992) found an unexpected grouping of Droseraceae and Nepenthaceae with Caryophyllales; the latter have been considered to have no particularly close relatives, other than perhaps Plumbaginaceae and Polygonaceae (Cronquist, 1981). This clade appears in all trees, even non-molecular, with a remarkably similar composition (Figs. 2B, 3A, 4A). Most taxa of the clade formed by Rhabdodendraceae (1), Caryophyllales (2), Tamaricaceae (3), Frankeniaceae (4), Asteropeiaceae (5), Nepenthaceae (6), Droseraceae (7), Dioncophyllaceae (8), Ancistrocladaceae (9), Simmondsiaceae (10), Plumbaginaceae (11), and Polygonaceae (12), here termed as caryophyllids, have some taxa with tricolpate or polycolpate (stephanocolpate) pollen grains (2, 3, 4, 5, 7, 8, 9, 10, 11, 12; Erdtman, 1952; Cronquist, 1981; 129). Many (2, 5, 6, 7, 8, 9, 10, 11, 12) also have spinuliferous or punctitegillate pollen sexine (Erdtman, 1952; 135). The similarity of pollen grains of some Polygonaceae and some Caryophyllales was noted by Erdtman (1952). Likewise the resemblance of pollen of Droseraceae and Nepenthaceae is noteworthy (e.g., Erdtman, 1952; Basak & Subramanyam, 1966; Takahashi & Sohma, 1982). Anomalous secondary growth seems to be particularly well represented in the caryophyllids, occurring in Rhabdodendraceae, Caryophyllales, Frankeniaceae, Dioncophyllaceae, Simmondsiaceae, and Plumbaginaceae (Carlquist, 1988a). Similarly, interxylary phloem occurs in several taxa: Rhabdodendraceae (Record, 1933), Caryophyllales, Simmondsiaceae (Bailey, 1980), Plumbaginaceae, and Polygonaceae. A character-state that was coded as present in only seven taxa outside the extended caryophyllids is the presence of maximally biseriate wood rays, displayed in Frankeniaceae, Asteropeiaceae, Dioncophyllaceae, Ancistrocladaceae, Droseraceae, and Simmondsiaceae (Metcalfe & Chalk, 1950; Carlquist, 1988a; Carlquist & Wilson, 1995).

The caryophyllids, except for Rhabdodendraceae, are further characterized by the presence of only alternate intervessel pitting (secondary xylem present in 2, 3, 4, 5, 7, 8, 9, 10, 11, 12; 184). The exclusive occurrence of the alkaloid ancistrocladine in Amaranthaceae (Arora & Metha, 1981; 85), Dioncophyllaceae, and Ancistrocladaceae (Hegnauer, 1962–1994) also suggests a degree of relatedness. All caryophyllid families for which information was available (3, 4, 6, 7, 9, 11, 12) have an endosperm provided with starch grains (161); only ten other taxa in the matrix share this condition. Tamaricaceae were previously put into the "Nelkengruppe," roughly corresponding to modern concepts of Caryophyllales, by Hallier (e.g., 1914). A tendency linking Tamaricaceae and Frankeniaceae is the presence of exotestal cells with convex surfaces, being represented as papillae in Frankeniaceae or as hairs in Tamaricaceae. Netolitzky (1926) mentioned that the chalazal hair tuft in Tamaricineae is first developed as papillae. Corner (1976) also postulated a link of Frankeniaceae to Tamaricaceae through exotestal morphology. Moreover, Tamaricaceae as well as Frankeniaceae have appendages on the ventral side of their petals. Airy Shaw (1951) suggested a close affinity of Droseraceae, Nepenthaceae, Ancistrocladaceae, and Dioncophyllaceae. Schmid (1964) added new evidence for this grouping. The latter alignment, containing three carnivorous families (Droseraceae, Nepenthaceae, and Dioncophyllaceae) with different trapping systems, has been supported by Hegnauer (1962–1994) on biochemical grounds.

The presence of the naphthoquinones plumba-

gine (99), droserone (100), and related 1,4-naphthoquinones is another link between Nepenthaceae, Droseraceae, Ancistrocladaceae, Dioncophyllaceae, and Plumbaginaceae (Hegnauer, 1962–1994; Zenk et al., 1969; Durand & Zenk, 1974; Lavault & Bruneton, 1980; Williams et al., 1994); these compounds are otherwise known to be accumulated only by several species of Iridaceae and Ebenaceae (Hegnauer, 1962–1994).

It is mainly the coincidence of these trends in chemistry and pollen morphology that places the families mentioned above into the expanded caryophyllid clade in the non-molecular tree. Thus, it is the coding of the presence of variably exhibited specialized traits that is responsible for the presence of the caryophyllid clade in nearly the same composition as in the *rbc*L trees. Rhabdodendraceae, which fall into the asterids in the non-molecular trees (Fig. 2A), presumably do so because they have unitegmic ovules (see below); with the weak support (69%) present in the *rbc*L data for the expanded caryophyllids, Rhabdodendraceae move into this clade in the combined tree.

One of the remarkable aspects of the caryophyllid clade is the diversity of life history strategies that is found among these taxa. Many of these taxa are adapted to either xeric or saline conditions, and some (i.e., Plumbaginaceae, Frankeniaceae, and Tamaricaceae) have multicellular glands that excrete salt (Hill & Hill, 1976; character not coded), whereas others such as Droseraceae, have similar glands that produce mucilage and enzymes used to trap and digest insects (Juniper et al., 1989).

A similar Caryophyllidae s.l. was also inferred from 18S rDNA data (Soltis et al., 1997b). Comparing the present non-molecular, *rbc*L, and combined trees, the caryophyllids appear in no consistent position with respect to the rosids or asterids. Future combined studies may establish the interrelationships of these clades.

Asteridae s.l. The larger asterid clade found with *rbc*L (Olmstead et al., 1992, 1993; Chase et al., 1993; Savolainen et al., 1994; Soltis et al., 1997b) has been remarkably consistent in composition as well as in the general patterns of relationships. This same grouping is present in the non-molecular trees (Fig. 2A), except that some unexpected taxa have additionally been placed here (i.e., Gunneraceae, Sabiaceae, Rhabdodendraceae, and Santalales), presumably because these are highly autapomorphic (e.g., Gunneraceae) or they have unitegmic ovules like asterids (e.g., Sabiaceae, Rhabdodendraceae). The absence of these groups from the asterids with *rbc*L analysis can be interpreted as meaning that the distribution of unitegmic ovules shows some degree of homoplasy. The presence of unitegmic ovules is a consistent character-state in most asterid clades. In a clade corresponding to asterid I, II, and IV of Chase et al. (1993), most taxa have unitegmic ovules (Hydrangeaceae, Cornales, Oncothecaceae, Sphenostemonaceae–Aquifoliaceae, Icacinaceae, Eucommiales, Dipsacales, Campanulales, Solanales, Gentianales, Scrophulariales, Escalloniaceae, Pittosporaceae, Araliales, Menyanthaceae, and Loasaceae; 137). In addition to characters correlated to some degree with unitegmic and tenuinucellar ovules (137, 139; the correlation including the presence of an integumentary tapetum and endosperm haustoria), the asterids also have a higher percentage of taxa with united sepals (215), and especially with united petals (217), than rosids; this is much more evident than in the more restricted definition of asterids by either Cronquist (1981) or Takhtajan (1987). Caricaceae are the only rosid family in this analysis in which all genera have united petals (best developed in the male flowers). In addition to the tendency for the union of perianth whorls, asterids show a higher degree of haplostemony than rosids, a character that is perhaps functionally linked to the more synorganized perianth/androecium. The core asterids (sensu Cronquist, 1981), Solanales, Campanulales, Gentianales, and Scrophulariales, are held together by alternate vessel side-wall pitting (184), simple vessel perforations (185), and rounded vessel transverse section (Metcalfe & Chalk, 1950; 187).

Loasaceae and Hydrangeaceae both show the presence of deutzioside (Bliss et al., 1968; Uesato et al., 1986), an iridoid compound known only from these two families (Hegnauer, 1962–1994). Other *rbc*L studies (Soltis et al., 1995a) demonstrated that these two families are sister taxa (but an *rbc*L sequence for Loasaceae was unavailable for the present study). Iridoid compounds occur in 19 taxa in our matrix, 16 of which belong to the extended asterids. Light-colored, obdurate, protruding, nonglandular leaf teeth characterize different taxa of Hydrangeaceae (character not coded; O. Nandi, pers. obs.). The investigation of leaf teeth in the sister groups of Hydrangeaceae is potentially interesting. Hydrangeaceae and Cornales share the tendency to form inflorescences with showy, sometimes white leafy organs at their periphery. In Cornales (*Cornus* spp., *Davidia*) these organs are large bracts, differing only slightly from normal foliage leaves. In Hydrangeaceae these organs are the sepals (genera of Hydrangeeae; Engler, 1891). This tendency has not been coded in our matrix (the

organs involved are not homologous). The synorganization of flowers into pseudanthia is a recurring phenomenon in asterids IV and II (sensu Chase et al., 1993; character not used in this analysis).

Taxa having iridoid compounds that are not included in asterids s. str. (sensu Cronquist, 1981) are Hydrangeaceae, Cornales, Icacinaceae, Eucommiales, Escalloniaceae, Loasaceae, Fouquieriaceae, Symplocaceae, Ericales, Sarraceniaceae, and Actinidiaceae (Hegnauer, 1962–1994). These are all asterids in the *rbc*L and combined trees (Figs. 3A, 4A), and also, with one exception, in the non-molecular tree (Fig. 2A).

The presence of a theoid exotesta (152), i.e., an exotesta with lignified and often pitted radial and inner walls (cf. Huber, 1991), links some asterid taxa: Sphenostemonaceae–Aquifoliaceae (*Ilex*; Corner, 1976), Solanales (Solanaceae, e.g., *Atropa*, *Browallia*, *Cestrum*, *Lycium*, *Mandragora*, *Nicandra*, *Nicotiana*, *Petunia*, *Solanum* p.p. *Withania*; Corner, 1976), Dipsacales (Caprifoliaceae, e.g., *Lonicera*; Corner, 1976), Gentianales (Loganiaceae, e.g., *Strychnos*, Gentianaceae, e.g., *Fagraea*; Corner, 1976), Pentaphylacaceae (*Pentaphylax*; Huber, 1991), Marcgraviaceae (*Souroubea*; Huber, 1991), Symplocaceae (*Symplocos*; Huber, 1991), Diapensiaceae (*Diapensia*; Netolitzky, 1926), Ericales (Empetraceae, e.g., *Corema*; Huber, 1991), Sarraceniaceae (Corner, 1976), Clethraceae (Corner, 1976), Actinidiaceae, slightly differentiated in *Saurauia* (Corner, 1976), and Theaceae (Adinandreae; Corner, 1976).

The occurrence of cantleyoside (48), an ester of the iridoid glucoside loganin with the secoiridoid glucoside secologanic acid, is restricted to a few taxa of the asterids II (sensu Chase et al., 1993). This compound is known only from Icacinaceae, Dipsacales, and Campanulales (Hegnauer, 1962–1994; Sévenet et al., 1971; Jensen et al., 1979; Murai et al., 1985; Harborne & Baxter, 1993). The lignan eucommin A (53) is only known from Eucommiales and Gentianales, a fact that supports the placement of Eucommiales in the asterid I clade (sensu Chase et al., 1993; Hegnauer, 1962–1994; Deyama et al., 1985; Harborne & Baxter, 1993).

Oxalate druses (Metcalfe, 1950) are absent from the clade formed by Balsaminaceae (1), Pentaphylacaceae (2; no *rbc*L data), Marcgraviaceae (3), Pellicieraceae (4), and Tetrameristaceae (5). All but Pentaphylacaceae have the trait of forming oxalate raphides (1, 3, 4, 5), which is unusual for dicots. A subclade of asterid III (sensu Chase et al., 1993) has a persisting free-central column in loculicidal capsules: Ericales (Ericaceae, Epacridaceae; Drude, 1891b, c; Clethraceae; Drude, 1891a); and Theaceae (Cronquist, 1981; 252). Ericales and Sarraceniaceae are linked by the presence of protruding diffuse placentae. Scytopetalaceae and Lecythidaceae share stratified phloem (Metcalfe & Chalk, 1950), cortical vascular bundles (Metcalfe & Chalk, 1950), and a nectary disk in the flowers (Scytopetalaceae, Letouzey, 1961; Lecythidaceae subfam. Planchonioideae, Endress, 1994a).

Rosidae. Relatively minute embryos (compared to seed size) seem more frequent in the first-branching dicots (magnoliids, hamamelids, some of the first-branching asterids) than in the more nested clades such as Caryophyllidae s.l. and Rosidae. Only 4 out of 74 rosid taxa for which the character has been coded exhibit minute embryos (163): Paeoniaceae, Saxifragales s. str. (in our study, Saxifragales s. str. include Grossulariaceae, Haloragaceae, Penthoraceae, Saxifragaceae; without Vahliaceae, Greyiaceae, Francoaceae, Parnassiaceae, and Lepuropetalaceae; cf. Takhtajan, 1987), Peridiscaceae, and Tremandraceae. A possible synapomorphy of Paeoniaceae and Saxifragales s. str. is the presence of an exotestal palisade with thickened outer walls (151) in seeds of *Paeonia* and *Ribes* (Netolitzky, 1926; Corner, 1976). The ridges formed by radial elongation of the exotestal cells in certain Saxifragaceae (similar also in Crassulaceae), according to Corner (1976), "suggest the vestige of a uniformly palisade-like exotesta" in this family. For an extensive study of the Saxifragaceae s.l. and suggestions on their naming see Soltis and Soltis (1997).

Another unexpected grouping in the *rbc*L tree by Chase et al. (1993) is supported in the combined tree. Vochysiaceae/Myrtales (97% bootstrap) have methylated ellagic acids (62), intraxylary phloem (171), vestured pits in vessels (Bailey, 1933; van Vliet & Baas, 1984; Carlquist, 1988a; 183), and unilacunar nodes (Cronquist, 1981; Dahlgren & Thorne, 1984; 190).

Tropaeolaceae, Akaniaceae, and Bretschneideraceae, in addition to their glucosinolate production (36), are linked by tricarpelly (233–235). Caricaceae, Capparales, and Salvadoraceae, three glucosinolate-producing taxa, each contain taxa with a fibrous exotegmen (Corner, 1976). Capparales and Salvadoraceae concur in the presence of intra- or interxylary phloem (Carlquist, 1988a; character partially represented in 171). The presence of a single crystal layer (with one oxalate crystal per cell) in the endotesta in Caricaceae (Corner, 1976) and some Capparales (Resedaceae; Corner, 1976) could be a further argument for their affiliation (155). The glucosinolate clade is also present in the

18S rDNA trees (Soltis et al., 1997b) and *atp*B trees (unpublished).

In Malvales s.l., all families have only simple perforations in the secondary xylem (Metcalfe & Chalk, 1950; 185), and all but two families, Cistaceae and Bixaceae, have representatives with mucilage cells or mucilage cavities (Metcalfe & Chalk, 1950; Cronquist, 1981; 119). All taxa for which the character is known (i.e., all except Sarcolaenaceae and Sphaerosepalaceae) are characterized by the occurrence of centrifugal or rarely (Thymelaeaceae; Heinig, 1951) lateral polyandry (Hirmer, 1918; Gore, 1935; Corner, 1946; Van Heel, 1966; Sattler, 1973; Woon & Keng, 1979; Cronquist, 1981; Ronse Decraene, 1989, 1992; Bayer & Hoppe, 1990; Nandi, 1998b; 224). Another synapomorphic character complex for the extended Malvales can be found in seed anatomy. All families for which information is available have representatives with the exotegmen differentiated as a palisade layer (Thymelaeaceae, Sphaerosepalaceae, Malvales s. str., Cochlospermaceae, Bixaceae, Cistaceae, Dipterocarpaceae, and Sarcolaenaceae; Corner, 1976; Nandi, 1998a; 157). An exotegmic palisade occurs only rarely outside of this group (e.g., Trochodendrales, Huaceae, and Euphorbioideae). Malvales s.l. are also linked by the presence of wedge-shaped phloem rays in Thymelaeaceae, Sphaerosepalaceae, Malvales s. str., Cochlospermaceae, and Bixaceae (unknown for Sarcolaenaceae; 170). Moreover, most representatives of Malvales s.l. (except Thymelaeaceae) display a stratified phloem (Metcalfe & Chalk, 1950), a character-state known from just 19 other taxa in this analysis.

Sarcolaenaceae (1), Malvales s. str. (2), Cochlospermaceae (3), Cistaceae (4), Dipterocarpaceae (5), and Bixaceae (6) share the presence of stellate hairs (in 2, 4, 5, 6) and peltate scales (in 1, 2, 3, 4, 5, 6; Metcalfe & Chalk, 1988). This group is also characterized by palmate leaf venation (in Tiliaceae, Sterculiaceae, Bombacaceae, Malvaceae, Cochlospermaceae, Bixaceae, and some *Cistus* species; 198) and frequent tricarpelly (233–235). Cochlospermaceae, Bixaceae, Cistaceae, Dipterocarpaceae, and Sarcolaenaceae show the presence of a bixoid chalazal region in the seed (Nandi, 1998a; definition see Appendix 4; 159) as a non-paralleled apomorphy. Moreover, the group is characterized by the absence of a nectary disk (231), and by parietal placentation (241), and large, curved embryos [Cochlospermaceae, Bixaceae, Cistaceae, Dipterocarpaceae (Pakaraimaeoideae, Dipterocarpoideae) have large, curved embryos; Janchen, 1925; Pilger, 1925a, b; Maguire & Ashton, 1980; Cronquist, 1981; Nandi, 1998a)]. Vestured pits are found in many representatives of the group [*Bixa* (Solereder, 1899), *Cistus*, Dipterocarpaceae (Monotoideae: Baas & Werker, 1981; Pakaraimaeoideae, Dipterocarpoideae), Sarcolaenaceae (Morton, 1995), not in *Cochlospermum*; O. Nandi, pers. obs.; 183]. Cistaceae, Dipterocarpaceae, and Bixaceae share the absence of prodelphinidins (60). Bixaceae and Cistaceae share a starchy endosperm (161) with similar structure of larger starch grains (character not coded; Nandi, 1998a). As in the expanded caryophyllids, it is again a set of specialized character-states that establishes the pattern in the non-molecular trees that then parallels the pattern seen in the *rbc*L trees for the same taxa.

Another unexpected clade, identified in the 1993 *rbc*L trees, was an expanded Malpighiales clade that included families such as Euphorbiaceae, Passifloraceae, Ochnaceae, and Violaceae. This clade is also present in our *rbc*L and combined analyses (Figs. 3B, 4B). Many of these taxa have a fibrous exotegmen (157). Together with the three taxa in the mustard-oil group, this assemblage accounts for 19 of 24 taxa exhibiting a fibrous exotegmen: Connaraceae, Oxalidaceae, and Elaeocarpaceae in Cunoniales; Celastrales s. str.; and Irvingiaceae, Euphorbiales (Phyllanthoideae sensu Corner, 1976), Violaceae, probably Kiggelariaceae, Flacourtiaceae s. str., Scyphostegiaceae, Erythroxylaceae, Malpighiaceae, Linales s. str., Ochnaceae (Sauvagesioideae), Medusagynaceae, and Trigoniaceae (Corner, 1976; probable indication of the character for *Medusagyne* by Dickison, 1990). A fibrous exotegmen was also recently described from Rhizophoraceae (*Crossostylis*; Setoguchi et al., 1992), supporting the alliance of this family with rosids having fibrous exotegmen (Malpighiales) and not with Theaceae, as suggested by the non-molecular trees (we became aware of this publication too late to include the character in the matrix). Conti et al. (1996) produced *rbc*L trees that showed Rhizophoraceae in Malpighiales. It is noteworthy that Rhizophoraceae and Erythroxylaceae have tropane alkaloids (character not coded). This alkaloid class is otherwise known only in dicots from Proteaceae, Convolvulaceae, Solanaceae, *Cochlearia* (Brassicaceae), and Elaeocarpaceae. The related hygroline alkaloids are confined to Rhizophoraceae and Erythroxylaceae and are known to occur in only two other families [Solanaceae, Brassicaceae (*Cochlearia*); Hegnauer, 1962–1994].

With present knowledge, hostplants of the butterfly genus *Cymothoë* (Nymphalidae: Limenitinae) include only taxa from a few families near Violaceae (character not used in computation); these

families are Clusiaceae, Euphorbiaceae, Dichapetalaceae, Violaceae, Kiggelariaceae, and Flacourtiaceae s. str. (Ackery, 1988). This is one of the rare non-molecular patterns linking Clusiaceae to Euphorbiaceae, and both to Flacourtiaceae.

Violaceae, Kiggelariaceae, Flacourtiaceae s. str., and Scyphostegiaceae are linked by the presence of septate fibers (Metcalfe, 1956; Miller, 1975; 176). The clade formed by Salicaceae, Flacourtiaceae s. str., and Kiggelariaceae has thin wood-fiber walls (Appendix 4; Metcalfe & Chalk, 1950; Miller, 1975; 175), lack of calyx-corolla differentiation (210), absence of alignment of the carpels with the median tepals or petals (232), and loculicidal capsules (251). The close alliance of Salicaceae to Flacourtiaceae s. str. is further suggested by the lepidopteran genus *Cupha* (Nymphalidae: Argynninae) feeding exclusively on this group (on *Hydnocarpus*, Kiggelariaceae; *Homalium*, *Xylosma*, *Scolopia*, Flacourtiaceae s. str.; and on *Salix*, Salicaceae; Ackery, 1988). Another argynnine genus (*Phalanta*; Ackery, 1988) feeds mainly on *Rinorea*, *Melicytus*, *Viola* (Violaceae), *Dovyalis*, *Flacourtia*, *Scolopia*, *Trimeria*, *Xylosma* (Flacourtiaceae s. str.), *Rawsonia* (Kiggelariaceae), *Populus*, *Salix* (Salicaceae), and *Maytenus* (Celastraceae). In addition, both Flacourtiaceae s. str. (*Xylosma*, *Poliothyrsis*) and Salicaceae (*Populus*) have representatives containing the phenolglucoside nigracin, not known from any other family (Hegnauer, 1962–1994; Thieme & Benecke, 1966, 1970; 95). Flacourtiaceae s. str. and Kiggelariaceae, two somewhat preliminary taxa derived from the traditional Flacourtiaceae (e.g., Takhtajan, 1966; Cronquist, 1981), are linked by the presence of finely reticulate pollen ectexine (Keating, 1975; 136), a fibrous exotegmen (in *Casearia*, *Flacourtia* of Flacourtiaceae s. str.; in *Oncoba*, uncertain position, probably Flacourtiaceae s. str.; probably also in *Hydnocarpus*, Kiggelariaceae; Corner, 1976; 157), a hypostase in the seeds (160), septate fibers in the overwhelming majority of genera (Miller, 1975; 176), opposite in addition to alternate vessel side-wall pitting in the wood of the anatomically most basal representatives (*Erythrospermum*, *Carpotroche*, *Mayna*, *Hydnocarpus*, Kiggelariaceae; *Azara*, Flacourtiaceae s. str.; Miller, 1975; 184), scalariform vessel perforation plates in some representatives (185), and epidermal leaf crystals (196). Within the Flacourtiaceae s. str./Kiggelariaceae assemblage, there seems to be a negative correlation between genera bearing cyanogenic glycosides of the gynocardin type (49) and the genera displaying salicoid teeth (sensu Hickey & Wolfe, 1975; Appendix 4; 201). The two characters seemingly never occur together in the same genus. In addition to the genera described to have salicoid teeth (*Idesia*, *Populus*, *Salix* in Hickey & Wolfe, 1975; *Prockia* in Morawetz, 1981), twelve other genera from the tribes Homalieae, Scolopieae, Prockieae, and Flacourtieae (sensu Lemke, 1988) have been found to contain species with salicoid teeth: *Dissomeria*, *Byrsanthus*, *Calantica*, *Carriera*, *Flacourtia*, *Homalium*, *Ludia* (not well developed), *Oncoba* (in Oncobeae in the system of Lemke, 1988), *Poliothyrsis*, *Scolopia*, *Trimeria*, and *Xylosma* (O. Nandi, pers. obs.). A broad survey of angiosperm leaves in the herbaria of Zürich (Z and ZT), Geneva (G), and Vienna (WU) indicated that salicoid leaf dentation is a good systematic marker, and that similar tooth types occur only rarely outside of Flacourtiaceae s. str. and Salicaceae (O. Nandi, pers. obs.; e.g., *Tetracentron*). The fact that *Oncoba* lacks both gynocardin-like compounds and has salicoid teeth in addition to glands on the distal end of the petioles (also found in some of the genera with salicoid teeth) indicates that this genus is not well placed among the tribe Oncobeae (the definition of the tribe is based on floral morphology following Warburg, 1894). The tribe Casearieae (sensu Lemke, 1988) lacks both gynocardin-like compounds and salicoid teeth. Moreover, the two closely related butterfly genera *Siderone* and *Zaretis* (Nymphalidae: Charaxinae: Anaeini), are known to feed nearly exclusively on members of this tribe (*Casearia*, *Laetia*, *Ryania*, and *Zuelania*; Ackery, 1988). Other genera of the subtribe Anaeini feed mainly on Euphorbiaceae. This pattern could indicate that Casearieae are not immediately connected to other tribes of Flacourtiaceae s.l. Conversely, the genus *Cymothoë*, mentioned previously, feeds on *Casearia* (Casearieae), *Rawsonia* (Erythrospermeae), *Buchnerodendron*, *Caloncoba* (Oncobeae), *Kiggelaria* (Pangieae), and *Dovyalis* (Flacourtieae), as well as on Clusiaceae, Euphorbiaceae, and Dichapetalaceae (Ackery, 1988). A relationship of Kiggelariaceae to Passiflorales is suggested by the fact that at least three butterfly species of *Acraea* subg. *Acraea* (Nymphalidae: Acraeinae: sensu Pierre, 1984) feed on Kiggelariaceae, and Passifloraceae tribes Paropsieae (no molecular data available) and Passifloreae (an extrinsic character, not in the matrix). The first molecular insights into Flacourtiaceae s.l. using *rbc*L sequence data information were provided in Chase et al. (1996); a great deal more study of this and related families will be required to establish proper family circumscriptions.

A relationship of Violaceae to the flacourtiaceous line is further indicated by the hostplants of *Acraea cerasa*, found to be an early-branching representa-

tive of the subgenus *Acraea* in a morphological cladistic study by Pierre (1984). This species is known to feed on both *Rinorea* (Violaceae) and *Rawsonia* (Kiggelariaceae). Other species of subgenus *Acraea* feed exclusively on Violaceae and Passiflorales. *Acraea* subg. *Acraea* thus seems to show loose coevolutionary correlations with representatives of Violaceae, Flacourtiaceae s. str., Kiggelariaceae, Passifloraceae, and Turneraceae.

Linales s. str., Passiflorales, and Euphorbiales also share the exclusive capacity of producing the cyanogenic diglucosides linustatin and neolinustatin (character-states not included in the matrix for Euphorbiales; 29, 30). The two compounds are transport-forms of the widely distributed monoglucosylated cyanogenes linamarin and lotaustralin (Hegnauer, 1962–1994; Smith et al., 1980; Selmar, 1993; Frehner et al., 1990; Mkpong et al., 1990). They are formed during seed development (*Linum*), seed germination (*Hevea*), or tuber formation (*Manihot*).

Quiinaceae, Ochnaceae, and Medusagynaceae have at least some taxa with contorted petal aestivation (*Touroulia*, Quiinaceae, Engler, 1925; Ochnaceae, Gilg, 1925; Medusagynaceae, Engler & Melchior, 1925). Links of Ochnaceae to Medusagynaceae can be seen in the common presence of stratified phloem (known for *Godoya* in Ochnaceae and Medusagynaceae, Metcalfe & Chalk, 1950), cortical vascular bundles in the stem, septicidal capsules, and a persistent free-central column in the fruits (Fay et al., 1997).

Connaraceae and Oxalidaceae (here in Cunoniales; Figs. 3B, 4B) share the absence of ellagic acid and the presence of rapanone, a benzoquinone (Fieser & Chamberlain, 1948; Hegnauer, 1962–1994). Rapanone is only known from a few angiosperm families, including Myrsinaceae, according to Hegnauer (1962–1994). Connaraceae and Oxalidaceae are further linked on the basis of sievetube plastids of the PIc-type (Behnke, 1981; 107), the absence of oxalate druses (Metcalfe & Chalk, 1950; 112), a short exotestal palisade [Connaraceae (*Cnestis, Connarus* spp., *Jollydora, Rourea*), Oxalidaceae (*Averrhoa*); Corner, 1976; 151], endotestal crystals [Connaraceae (*Jollydora*), Oxalidaceae (*Averrhoa, Oxalis*); Corner, 1976; 155], fibrous exotegmen [Connaraceae (*Cnestis, Jollydora, Rourea*), Oxalidaceae (*Averrhoa, Oxalis*); Corner, 1976; 157], and exclusively uniseriate wood rays (181).

Celastrales s. str. and Plagiopteraceae are linked by the common presence of epidermal crystals in the leaves (Baas et al., 1979; 196), the occurrence of weakly crassinucellar ovules in representatives of both taxa (*Celastrus* and *Cassine* (as *Elaeodendron*), Celastrales s. str., Johri et al., 1992; *Plagiopteron*, Tang, 1994; 139), and an integumentary tapetum (Johri et al., 1992; Tang, 1994; 138).

Cephalotaceae, Eucryphiaceae, Brunelliaceae, and Cunoniaceae all have representatives with follicles or ventricidal capsules (Engler, 1930; Bausch, 1938; Cronquist, 1981; 251), and Brunelliaceae and Cunoniaceae have opposite leaves (191) with frequently craspedodromous venation (O. Nandi, pers. obs.; 199). A similar cunonioid clade was found in the 18S rDNA trees (Soltis et al., 1997b).

The taxa with nitrogen-fixing root symbionts in at least some genera [Fabaceae, Cucurbitales (Datiscaceae), Coriariaceae, Faganae (Myricaceae, Betulaceae, Casuarinaceae), Rosaceae, Rhamnaceae, Urticales (Ulmaceae), and Elaeagnaceae; 105], with the exception of Fabaceae, are placed in a monophyletic clade in the combined tree. In the *rbc*L trees (Fig. 3B), Fabaceae are also members of this clade, but they are placed outside the clade in the combined tree (Fig. 4B). Fabaceae, Myricaceae, Betulaceae, Casuarinaceae, Ulmaceae, and Elaeagnaceae are known to contain nodule hemoglobin (Landsmann et al., 1986; this character was not used in the non-molecular matrix). The hostplant taxa of the hyphomycete *Tubercularia ulmea* [Rhamnaceae (*Rhamnus*), Elaeagnaceae (*Elaeagnus*), Urticales (*Ulmus*); Farr et al., 1989] form a monophyletic clade in the trees derived from the combined data set, a fact that could point to a coevolutionary relationship of the fungus and these rosids. In both the 18S (Soltis et al., 1997b) and *atp*B trees (Savolainen et al., 1996), this same nitrogen-fixing clade is present.

There are many other specific characteristics upon which some discussion could be made, but at this point in time, this is not appropriate. We have focused in the previous section on features that are of particular interest to us. The most significant outcome of these comparisons is that chemical and micromorphological (often palynological) data should be included as equally important characters as developmental and floral morphological traits in macrosystematic considerations. These characters seem to correspond most closely to the molecular results. Gross morphological traits, particularly phyllotaxy, presence of stipules, and perianth arrangement, appear especially unreliable for systematic interpretations at this level within angiosperms.

(C) TAXA FOR WHICH *rbc*L SEQUENCES ARE NOT AVAILABLE

Hydnoraceae (not included in our matrices) have been allied to Aristolochiales in some systems (e.g.,

Takhtajan, 1987). Characters of Hydnoraceae tending to be ancestral are monosulcate, di- or trisulcate as well as trichotomocolpate pollen (x-tomocolpate pollen known in Chloranthaceae, *Cabomba*, Saururaceae, and monocots), psilate exine, thick endexine as compared to the ectexine, unitegmic, orthotropous ovules (as in Ceratophyllaceae, but probably also correlated with the high ovule number and parasitism), a well developed perisperm (a character more widespread in basal than in advanced angiosperms), a minute embryo in the seed, non-arborescent growth form, and a perianth not differentiated into calyx and corolla.

Rafflesiaceae (not included in our matrices) are known to be heterogeneous both in pollen characters and macromorphology (Takhtajan et al., 1985). It is possible that the different families recognized by Takhtajan (1987), i.e., Rafflesiaceae s. str., Apodanthaceae, Mitrastemonaceae, and Cytinaceae, belong to distantly related groups. The occurrence of ellagitannins (characteristic for eudicots) and 2-, 3-, or 4-porate pollen grains in *Cytinus* and the tricolpate pollen grains in *Pilostyles* suggest the absence of a close relationship to *Rafflesia*, *Rhizanthes*, and *Sapria*, which have monosulcate or monoporate pollen (the recent 18S rRNA information on Rafflesiales by Nickrent, 1996, confirms the segregation of *Cytinus* from Rafflesiaceae s. str.). The occurrence of both a lamellate endexine and an atectate ectexine in the pollen of Rafflesiaceae s. str. (Takhtajan et al., 1985) is likely an ancestral character combination for angiosperms.

In the fossil record, epigynous angiosperm flowers from the Early Cretaceous of Portugal have been found (Friis et al., 1994). Partly, these flowers are of unclear systematic affinity; some of them have similarities with Laurales. In extant basal angiosperms epigynous flowers are comparatively rare, although they are present in several families. The fact that Hydnoraceae and Rafflesiaceae s. str. have epigynous flowers and the seemingly ancestral characters found in these two families call for their integration in the research on first-branching angiosperms. It would be especially interesting to include them in molecular systematic studies, because morphological and anatomical characters are difficult to assess (because of reductions due to parasitism). Analysis of 18S rDNA sequences would be the most likely source of useful information to address questions about these parasitic plants, but the high levels of divergence for these plants (Nickrent, 1996) coupled with the low levels of divergence for 18S rDNA found in angiosperms in general (Soltis et al., 1997b) are likely to make sequence evaluations unreliable.

Podostemaceae are another family with unusual biology for angiosperms in general, and are thus difficult to assess. In our non-molecular trees, they generally fall near or in the caryophyllids or less frequently Santalales. Despite rather incomplete data, character-states of systematic importance are the occurrence of silica bodies (111) and secretory cavities in the plant body, tricolpate pollen grains with spinulous exine and colpus membrane (Rutishauser, 1997; 130, 135), tenuinucellar ovules (139), suspensor haustoria (165), absence of calyx-corolla differentiation (210), rare occurrence of centrifugal androecium development (in *Mourera fluviatilis* Aubl., R. Rutishauser, pers. comm.; 224), prolonged stamen connectives (229), generally completely free styles [except for, e.g., "*Synstylis*" (*Polypleurum*); 237], micropyle formation by the outer integument (247), and septicidal capsules (251). Some of these characters may be seen as adaptations to the extreme habitat of Podostemaceae. Ueda et al. (1997), using *rbc*L sequence data, found that Podostemaceae are sister to Crassulaceae in the saxifragoid clade. Les and Philbrick (1996) reported extremely high levels of divergence for several Podostemaceae, but also concluded that they are sister to Crassulaceae.

Balanophoraceae are also highly reduced due to their parasitic ecology. They tend to align in extended caryophyllids. Triangular pollen grains (132) and the occurrence of similar embryo sacs could indicate a link to Santalales (Zweifel, 1939). The 18S rRNA analysis of Nickrent (1996) contradicted a close alliance of Balanophoraceae with Santalales. As with Podostemaceae, our matrix for Balanophoraceae has many gaps.

Strasburgeriaceae tend to be placed in basal asterids in the present non-molecular trees. Oncothecaceae are another small family placed in the asterids near Aquifoliaceae. Preliminary *rbc*L analyses support this position for *Oncotheca* (Savolainen & Chase, unpublished). Paracryphiaceae cluster with basal asterids or Eucryphiaceae.

Rhizophoraceae either fall near to the Stachyuraceae group or often are the sister group to Theaceae. Published and unpublished *rbc*L analyses support a placement of Rhizophoraceae in Malpighiales (Conti et al., 1996) near Erythroxylaceae (Chase et al., unpublished). The fibrous exotegmen in Rhizophoraceae, described by Setoguchi et al. (1992), would be in good agreement with the molecular results (see Discussion, section b).

Sarcolaenaceae align with Malvales s.l.; this is also confirmed with recent *rbc*L analyses (Conti et al., 1996). Cochlospermaceae also clearly align with Malvales s.l. as sister to a branch containing

Bixaceae and Cistaceae. Other analyses of *rbc*L also support this placement (Alverson et al., in press).

Bonnetiaceae, Elatinaceae (non-molecular data), and Clusiaceae (also with *rbc*L) are kept together by an exotegmen with lobate facets in tangential section (158). All three families have representatives with septicidal capsules (251). These three taxa are linked in the non-molecular trees. The close relationship of the three families was emphasized by Stevens (1991). Clusiaceae and Bonnetiaceae, in addition, are united by having representatives with arils (perhaps a vestigial aril in *Ploiarium*; Corner, 1976; 146) and protruding diffuse placentation (242). Preliminary *rbc*L studies of *Ploiarium* place it near Thymelaeaceae in Malvales s.l. (Chase, unpublished), but other Bonnetiaceae may not be related to *Ploiarium* (A. Weitzman, pers. comm.).

(D) CONCLUSIONS

Larger data matrices call for improved computational facilities, both in tree searches and in assessing confidence in the resulting clades (e.g., jackknife program, Farris et al., 1997). It has been recognized in these searches that the stronger the phylogenetic signal in a matrix, the easier it is to obtain reasonably short trees. In a sense, once one has found all the strongly supported clades, then the search is complete. Regardless of the manner in which weakly supported branches are arranged, there can be no confidence in the patterns so produced. In experiments with combining large *rbc*L, *atp*B, and 18S matrices, it has been noted that tree searches have become faster and production of a reasonably short tree length appears relatively easy (Soltis et al., 1997b; Chase & Savolainen, unpublished). We are optimistic that, as we add more data as well as more taxa, searches will in fact become easier rather than more difficult. Hillis's (1996) recent simulations and predictions also support the notion that increased sampling, both of genes and taxa, produces more accurate topologies; increase in accuracy by sampling more genes has been accepted for some time, whereas it has been a hotly disputed topic whether increased sampling of taxa also produces more reliable topologies (see for example Graur et al., 1996).

On the molecular-systematic side, improved topologies will be obtained by integrating and comparing more sequence-information from different genomes; this should allow us to have more confidence in the relationships obtained and to evaluate whether reticulate evolution through ancient hybridization or horizontal gene transfer has macrosystematic effects.

The work on the "classical" side is equally challenging. Cladistic analyses using non-molecular data should rely if possible on original observations of living plants, herbarium material, and anatomical slide collections, but also on primary and synoptic literature. Literature searches ideally should also include the older comparative literature (e.g., works by Baillon, Bentham & Hooker, Eichler, Engler & Prantl, Payer, Troll), which contains much useful and recently overlooked information.

Biochemical work can be refined, and new techniques will doubtless permit more detailed comparison of the different molecule classes. This promises to be a fruitful field, especially for families on which not much biochemical work has been done, such as Ceratophyllaceae, Hydnoraceae, Rafflesiaceae, Amborellaceae, Eupteleaceae, Sabiaceae, Didymelaceae, Aextoxicaceae, Strasburgeriaceae, Sphenostemonaceae, Oncothecaceae, Tetrameristaceae, Pellicieraceae, Pentaphylacaceae, Diapensiaceae, Scytopetalaceae, Dialypetalanthaceae, Bruniaceae, Plagiopteridaceae, Irvingiaceae, Sphaerosepalaceae, Diegodendraceae, and Sarcolaenaceae.

The study of the form and distribution of solid bodies in cells also reveals additional systematic information (e.g., oxalate crystals, starch grains; preliminary works by Czaja, 1969, 1978). The same holds true for investigations of plant hair structure.

Much more information on seed anatomy should also be sampled. Priorities again are small families of restricted distribution, as mentioned above. Seed anatomy has proven to be a good tool for macrosystematics in the present study (see also Corner, 1976; Huber, 1991; Seubert, 1993).

A character-rich field that has not yet received much attention from neobotanists is leaf structure (see Hickey & Wolfe, 1975; Klucking, 1986/1987/1988/1989/1991/1992/1995). Leaf morphology (leaf dentation, leaf venation patterns) is of great potential usefulness, especially in combination with paleobotany.

Rhizome, bulb, and root morphology and anatomy are presently not as well understood as, e.g., floral morphology. Floral ontogeny is a field in which new perspectives have been achieved by the use of SEM (e.g., Endress, 1994a; Tucker & Douglas, 1994; Erbar & Leins, 1996). Because of practical problems in acquiring different ontogenetic stages, there are still many groups that remain poorly known. Inflorescence types have been studied for many families and are likely to be valuable for phylogenetic analyses. Fruit anatomy has not

received much attention, probably also due to the large size of many angiosperm fruits. Recent works on Oleales (e.g., Rohwer, 1996) and Cornales (Reidt, 1997) show that comparison of fruit characters is systematically relevant.

As with intrinsic characters of angiosperms, extrinsic ones from fields such as ecology, paleoecology, paleobotany, biogeography, and hostplant and mutualistic relationships should also provide useful data. In the last field, more information should be sampled on hostplants of fungi, Lepidoptera, and other groups of organisms that tend to have taxa with restricted preference for particular angiosperms (perhaps also Orthoptera, Aphididae, and Chrysomelidae). Paleobotany is a promising field for providing insights on early angiosperm radiation and relationships to possible outgroups. It may also add evidence on the position of controversially positioned clades that cannot be assigned clearly to the asterids, rosids, or caryophyllids as described here and in Chase and Cox (in press).

We are optimistic about the prospects for improved analyses of all classes of data. This study provides one example of how this approach can succeed, but a great deal more work on methods of coding characters is needed. In which cases can tendencies be coded as uniform characters for families in which polymorphisms occur? Should a family or order, no matter how clearly supported as monophyletic, be used as a terminal? These results appear to demonstrate that this approach can succeed with both molecular and non-molecular data and that the phylogenetic content of characters so coded is not terribly distorted by this type of summarization. We suspect that, if the patterns are robust, different codings will provide similar results. What is most needed is not a dogmatic approach to character coding and skepticism of the potential for various coding methods to succeed, but an empirical evaluation of real data using consistent methods. Too much emphasis on methodological matters will only serve to impede progress. We maintain that the barriers to creating large matrices and performing analyses on large data sets have less to do with the data collection and analysis than with much skepticism of the process itself.

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Appendix 1. Non-molecular data matrix.

dill.mat5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
		sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	Al a	amx	dhu	prot	trigl	taxi	proa	hete	card	valv	linar	lotar	linur	neol	tyro	prun	sam	zier	holo	gluc	dihy	acet	eleo	myr
1	Ceratophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
2	Chloranthaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
3	Nymphaeaceae	C	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
4	Amborellaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
5	Austrobaileyaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	?
6	Illiciales	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
7	Winterales	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
8	Monocotyledons	C	A	C	?	A	A	A	?	?	?	A	?	?	?	?	?	A	C	C	A	C	C	A	C	A	C	A	C	C	A	A	A	A	A	A	C	A	A	A	A
9	Aristolochianae	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C
10	Laurales	C	C	C	?	?	?	?	A	A	A	?	?	?	?	?	?	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
11	Myristicaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C
12	Annonales	C	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A
13	Magnoliales	C	C	C	?	?	?	A	C	C	?	?	?	?	?	?	?	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
14	Ranunculidae	C	C	C	?	A	A	A	A	A	A	A	A	A	A	?	?	C	A	C	C	C	C	A	A	A	A	C	C	C	A	A	A	A	A	A	A	A	C	A	A
15	Eupteleaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
16	Platanaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
17	Nelumbonaceae	C	C	C	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
18	Trochodendrales	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?
19	Proteaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	C	C	A	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
20	Buxaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	A	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
21	Sabiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?
22	Didymelaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
23	Myrothamnaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
24	Berberidopsidaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A	A	?
25	Gunneraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
26	Rhabdodendraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?
27	Simmondsiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
28	Caryophyllales	?	A	A	?	A	A	A	?	?	?	A	A	A	A	?	?	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
29	Asteropeiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
30	Plumbaginaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
31	Polygonaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
32	Dioncophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
33	Ancistrocladaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	A	?
34	Nepenthaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?
35	Drosеraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?
36	Tamaricaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?
37	Frankeniaceae	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?
38	Hamamelidales	A	A	A	C	?	?	?	A	C	C	?	?	?	?	?	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
39	Dilleniaceae	?	A	A	?	A	A	A	?	?	?	A	A	A	A	A	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	A
40	Vitaceae	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
41	Eucryphiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
42	Brunelliaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
43	Cunoniales	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?
44	Paeoniaceae	A	A	A	?	A	A	A	A	A	A	A	?	?	?	A	?	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	A
45	Cephalotaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
46	Crassulaceae	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A
47	Saxifragales s. str.	?	A	A	C	?	?	?	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A
48	Staphyleaceae	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
49	Elaeagnaceae	?	?	?	?	?	?	A	C	C	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
50	Rosaceae	?	A	A	C	?	?	?	A	A	A	?	?	?	?	?	A	A	C	A	A	A	A	A	C	C	A	A	A	A	A	C	C	A	A	A	A	A	A	C	A
51	Rhamnaceae	?	?	?	?	?	?	?	A	A	C	?	A	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
52	Fagaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
53	Cucurbitales	?	?	?	?	A	A	C	A	A	C	A	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?
54	Coriariaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
55	Urticales	?	?	?	?	A	A	C	C	C	?	A	A	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C

Appendix 1. Continued.

dill.mat6	2	41 asar	42 sesc	43 germ	44 myo	45 pinit	46 quel	47 deut	48 cant	49 cycl	50 simm	51 aust	52 kade	53 eucc	54 syrti	55 pino	56 dihy	57 galb	58 ilicar	59 vera	60 prod	61 elae	62 meli	63 stac	64 casi	65 tell	66 tellir	67 peck	68 gera	69 chlo	70 galli	71 epig	72 llavc	73 afze	74 davi	75 brlla	76 Ouri	77 euxi	78 nors	79 mac	80 beru
1	Ceratophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
2	Chloranthaceae	?	C	C	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	?	A	A	A	?	A	A	A	?
3	Nymphaeaceae	?	?	?	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	C	C	A	?	?	?	?	?	?	?	C	?	?	?	?	?	A	?	?	?	C
4	Amborellaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
5	Austrobaileyaceae	?	?	?	?	?	?	?	?	A	?	C	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A
6	Illiciales	A	C	C	A	A	A	A	A	A	A	?	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	Winterales	?	C	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	A
8	Monocotyledons	C	?	?	C	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	C
9	Anatolochianae	C	?	?	A	C	A	A	A	A	A	A	C	C	A	A	A	C	?	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
10	Laurales	C	C	C	C	A	A	A	A	A	A	C	A	A	C	A	A	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	C
11	Myristicaceae	?	A	A	C	?	?	?	A	?	A	A	A	A	A	C	C	C	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	C
12	Annonales	C	C	A	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	C
13	Magnoliales	C	C	C	A	C	A	A	A	A	A	A	A	A	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	C
14	Ranunculidae	A	C	A	C	A	A	A	A	A	A	C	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	A
15	Eupteleaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?
16	Platanaceae	?	?	?	?	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?
17	Nelumbonaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C
18	Trochodendrales	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	?
19	Proteaceae	?	A	A	A	A	C	A	A	A	A	A	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A
20	Buxaceae	?	?	?	?	C	?	?	?	A	C	A	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	?
21	Sabiaceae	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
22	Didymeiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
23	Myrothamnaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?
24	Berberidopsidaceae	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A
25	Gunneraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
26	Rhabdodendraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
27	Simmondsiaceae	A	?	?	?	C	?	?	?	A	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?
28	Caryophyllales	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	C
29	Asteropeiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
30	Plumbaginaceae	A	A	A	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	C	C	A	?	?	?	?	?	?	C	?	?	?	?	?	?	A	?	?	?	A
31	Polygonaceae	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A
32	Dioncophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
33	Ancistrocladaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C
34	Nepenthaceae	?	A	A	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
35	Droseraceae	?	A	A	?	?	?	?	A	?	A	?	?	?	?	?	?	?	?	?	C	C	A	?	?	?	?	?	?	C	?	?	?	?	?	?	A	?	?	?	?
36	Tamaricaceae	?	A	A	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	?	C	C	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A
37	Frankeniaceae	?	?	?	A	C	A	A	A	?	A	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	?	A	?	C	?	?	?	?	?	?	?	?
38	Hamamelidales	?	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	C	C	C	C	C	C	A	C	C	A	C	C	?	A	A	A	A	A	A	A
39	Dilleniaceae	A	A	A	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	C	?	C	?	?	?	A	?	?	?	A
40	Vitaceae	A	A	A	C	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	C	C	A	A	A	A	A	A	A	A	A	C	A	?	A	A	A	A	A	A
41	Euphytiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
42	Brunelliaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
43	Cunoniales	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	C	C	C	?	?	?	?	?	?	?	C	C	?	?	?	A	?	?	?	?
44	Paeoniaceae	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	C	?	?	?	?	?	A	?	?	?	A
45	Cephalotaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	?	?	?	?	?	?	C	?	?	?	?	C	C	?	?	?	A
46	Crassulaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	?	?	?	?	?	?	C	?	?	?	?	?	A	?	?	?	A
47	Saxifragales s. str.	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	C	C	C	A	A	A	C	A	A	C	A	A	A	A	A
48	Staphyleaceae	A	A	A	A	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	A	?	?	?	?	?	A	?	?	?	A
49	Elaeagnaceae	A	A	A	A	A	C	A	A	A	?	?	?	?	?	?	?	?	?	?	C	C	A	A	A	A	A	A	A	C	A	A	?	A	A	A	A	A	A	A
50	Rosaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C	A	C	A	C	A	C	A	A	A
51	Rhamnaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	?	?	?	?	?	?	?	C	?	?	?	?	C	A	?	?	C
52	Fagaceae	A	A	C	C	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	C	C	C	C	C	C	C	A	A	C	A	?	C	A	C	A	A	A
53	Cucurbitales	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	?	C	?	A	A	A	A	A	A	A	A
54	Coriariaceae	?	C	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	C	A	C	?	?	?	?	?	?	?
55	Urticales	A	C	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	C	C	A	?	A	A	A	A	A	C	C	A

dill.mat6	3	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16	s17	s18	s19	s20	s21	s22	s23	s24	s25	s26	s27	s28	s29	s30	s31	s32	s33	s34	s35	s36	s37	s38	s39	s40	s41	s42	s43	s44	s45	s46	s47	s48	s49	s50	s51	s52	s53	s54	s55
		roen	apor	triox	prot	anci	cam	indo	ixso	secc	corn	olea	artur	dam	cucl	nigr	arbs	napr	rapa	plur	dros	anth	pher	anth	actir	nitro	chro	siew	strat	rod	epic	SrO	oxal	elon	solit	crys	sphi	myri	oil c	muc	resir
1	Ceratophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	A	?	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	C	C	C	C	C	C	C
2	Chloranthaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	C	A	A	A	C	C	A	C	A	A	A	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A
3	Nymphaeaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	A	A	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
4	Amborellaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
5	Austrobaileyaceae	A	A	A	A	A	?	?	A	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	A	A	A	C	A	A	A	?	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
6	Illiciales	A	A	A	A	A	A	A	A	A	A	?	?	A	A	A	?	?	?	?	?	?	?	?	A	A	C	C	A	A	A	C	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
7	Winterales	A	A	A	A	A	A	?	A	A	A	?	?	A	A	A	?	?	?	?	?	?	?	?	A	A	A	C	A	A	C	A	?	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A
8	Monocotyledons	A	A	A	C	?	A	A	A	C	A	A	A	C	A	A	A	A	C	A	C	A	C	C	C	C	A	C	A	A	?	A	C	C	A	C	A	C	C	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
9	Aristolochianae	A	A	C	?	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	?	A	C	A	C	C	A	C	A	C	A	C	G	C	C	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C
10	Laurales	C	A	C	C	A	A	C	A	A	A	A	A	A	A	A	C	?	?	?	?	?	C	?	A	A	C	A	C	C	A	C	A	C	C	A	C	A	C	G	A	A	A	C	C	C	C	C	C	C	C	C	C	C
11	Myristicaceae	A	A	?	C	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	C	A	C	C	A	A	?	A	C	A	A	?	A	C	A	A	C	C	C	C	C	C
12	Annonales	C	C	C	C	A	A	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	C	C	A	C	C	A	C	A	C	A	A	A	C	A	C	C	C	C	C	C	C	C	C	C
13	Magnoliales	A	C	C	C	A	A	A	A	A	A	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	C	C	A	C	A	C	A	C	G	C	A	A	A	A	C	A	C	C	C	C	C
14	Ranunculidae	C	C	C	C	A	A	A	C	A	A	C	C	A	A	A	C	C	?	?	?	?	C	A	A	A	C	C	C	C	A	C	A	C	C	C	C	A	C	C	C	A	A	A	C	C	C	C	C	C	C	C	C	C
15	Buxtaleaceae	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
16	Platanaceae	?	?	?	?	?	?	?	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A	C	A	C	A	C	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
17	Nelumbonaceae	C	C	C	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	C	A	C	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
18	Trochodendrales	?	?	?	?	?	?	?	?	?	?	C	A	A	?	?	?	?	?	?	?	?	?	?	?	A	A	C	A	A	A	C	A	C	A	A	A	A	A	A	A	A	C	A	C	A	C	A	C	A	C	A	C	C
19	Proteaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	A	C	A	?	?	?	C	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
20	Buxaceae	?	?	?	?	?	A	?	A	A	A	A	A	A	A	A	?	C	?	?	?	?	?	?	?	A	C	A	?	?	?	A	C	A	C	G	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
21	Sabiaceae	?	?	?	?	?	A	A	C	A	A	A	C	A	A	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
22	Didymelaceae	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	A	?	?	?	?	?	?	?	A	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A
23	Myrothamnaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A	?	C	A	A	A	A	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	C
24	Berberidopsidaceae	A	A	A	A	?	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	C	C	G	C	A	A	A	A	?	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
25	Gunneraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	A	C	G	C	?	?	A	A	A	A	C	A	C	A	C	A	C	A	C	A	C
26	Rhabdodendraceae	?	?	?	?	?	?	?	?	?	?	C	A	A	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	?	?	?	?	?	?	?	?	?	?	?	?	A	C	?	C	?	C	A	C	?	C	A	C	?	C
27	Simmondsiaceae	?	?	?	A	?	A	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	?	?	?	A	A	C	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
28	Caryophyllales	A	A	A	A	C	A	C	A	A	A	C	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	C	A	A	A	C	C	C	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A
29	Asteropeiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
30	Plumbaginaceae	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	C	A	C	C	?	A	?	A	A	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	C	A	C	A	C	A	C	A	C	A	C
31	Polygonaceae	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	A	A	A	C	A	C	A	A	C	C	A	A	A	A	C	C	A	A	C	C	A	A	C	A	C	C	A	C	A	A	A	A	A	A	A	A
32	Dioncophyllaceae	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	?	?	?	C	A	C	A	A	A	A	A	A	?	A	A	A	C	?	?	?	C	A	G	C	A	A	A	A	A	A	?	?	?	?	?	?	?
33	Ancistrocladaceae	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	?	?	A	A	A	C	C	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	?	C
34	Nepenthaceae	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	C	A	C	C	A	A	A	?	A	A	A	C	A	A	A	A	C	C	A	A	A	C	A	A	A	C	A	A	C	A	A	C	A	A	C	A
35	Droseraceae	?	?	?	?	?	?	?	A	A	?	?	?	?	A	?	A	C	A	C	C	A	?	A	?	A	C	C	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
36	Tamaricaceae	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	?	?	?	?	?	A	A	A	A	A	A	C	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
37	Frankeniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	?	?	?	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
38	Hamamelidales	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	?	?	?	?	A	A	A	A	A	A	C	A	C	A	A	C	A	C	A	A	A	A	A	C	C	A	C	A	C	A	A	A	A	C	C
39	Dilleniaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	C	A	C	A	A	A	A	C	C	A	C	A	C	A	C	A	C	A	C	A	C
40	Vitaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A	C	C	A	C	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	A
41	Euoryphiaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	C	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
42	Brunelliaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	A	C	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
43	Cunoniales	?	A	A	A	A	A	A	A	A	A	?	?	?	?	A	?	A	A	A	A	A	A	?	A	A	A	C	A	C	C	A	C	A	C	A	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A
44	Paeoniaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	?	?	?	?	?	?	A	C	A	A	A	C	A	C	A	C	A	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
45	Cephalotaceae	?	?	?	A	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	A	C	A	C	A	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
46	Crassulaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?	?	?	?	?	A	C	A	A	A	C	C	A	C	A	A	C	A	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	C
47	Saxifragales s. str.	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	C	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
48	Staphyleaceae	A	?	?	?	?	A	?	A	A	A	C	A	A	A	A	A	?	?	?	?	?	A	A	?	A	A	A	C	?	?	?	A	C	A	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A
49	Elaeagnaceae	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	?	A	?	?	?	?	?	A	A	A	C	C	C	?	?	?	A	C	G	C	C	A	A	A	A	A	C	G	C	C	A	A	A	A	A	A	A	A
50	Rosaceae	A	A	A	A	A	A	C	A	A	A	A	A	C	C	A	C	A	A	A	A	A	A	C	A	?	C	C	A	C	A	A	C	G	C	C	A	A	A	A	C	A	C	G	C	C	A	A	A	A	C	A	A	A
51	Rhamnaceae	A	A	C	A	A	A	A	A	A	A	C	A	C	A	A	C	C	A	A	A	A	C	A	A	A	C	A	C	C	?	?	?	A	C	G	C	C	A	A	A	A	C	A	C	G	C	C	A	A	A	A	C	A
52	Fagales	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	C	C	A	A	A	A	A	A	A	A	C	C	C	A	C	A	A	A	C	A	C	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A
53	Cucurbitales	A	A	A	A	A	A	A	A	A	A	A	C	?	?	C	A	A	A	A	A	A	C	A	?	A	A	C	C	?	?	?	A	C	G	C	C	A	A	A	A	A	C	A	C	G	C	C	A	A	A	A	A	A
54	Coriaraceae	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	C	A	C	?	?	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
55	Urticales	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	A	A	A	A	C	C	A	A	A	A	C	C	A	A	A	?	?	?	C	C	C	C	A	C	A	A	A	A	C	A	C	A	C	A	C	A	A	A

Appendix 1. Continued.

dill.mat6	4	1 2 1	1 2 2	1 2 3	1 2 4	1 2 5	1 2 6	1 2 7	1 2 8	1 2 9	1 3 0	1 3 1	1 3 2	1 3 3	1 3 4	1 3 5	1 3 6	1 3 7	1 3 8	1 3 9	1 4 0	1 4 1	1 4 2	1 4 3	1 4 4	1 4 5	1 4 6	1 4 7	1 4 8	1 4 9	1 5 0	1 5 1	1 5 2	1 5 3	1 5 4	1 5 5	1 5 6	1 5 7	1 5 8	1 5 9	1 6 0
		lastic	fasc	pelts	denc	nonp	glan	anth	micr	polle	type	pola	trian	tnan	angi	sexi	type	inte	inte	nucc	peri	endc	occi	occu	occi	end	aril	pac	sarc	rumi	exot	exot	theo	tann	mas	endc	endc	exot	exot	bixo	hyp
1	Ceratophyllaceae	A	A	A	A	A	A	A	A/C	A	A	G	A	A	A	A	C	A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
2	Chloranthaceae	A	A	A	A	A	A	A	C	C	A	A	A	A	A	G	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	G	A	A	C
3	Nymphaeaceae	C	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	C	A	A	A	A	C	C	A	A	A	A	C	A	A	A	A	A	C
4	Amborellaceae	A	A	A	A	A	A	?	?	A	A	C	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	?	?	?	A	A	A	C	A	A	A	A	A	A	A
5	Austrobaileyaceae	A	A	A	A	A	A	C	C	C	A	G	A	A	A	G	G	A	A	A	A	?	?	?	?	G	A	C	C	C	A	A	A	C	A	A	A	G	A	A	A	A
6	Illiciales	A	A	A	A	A	A	C	C	G	C	C	A	A	A	G	G	A	A	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	C	?	A	A	A	A	A
7	Winterales	A	A	A	A	A	A	A	C	C	A	C	A	A	A	G	G	A	A	A	C	C	A	A	A	A	A	A	A	A	C	A	C	A	C	A	C	A	A	A	A	C
8	Monocotyledons	A	A	?	?	A	?	A	A	C	A	A	A	A	A	G	C	A	A	A	C	C/G	C	A	A	A	A	?	A	C	A	A	A	A	A	A	?	A	G	A	A	C
9	Aristolochiinae	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A	A	C	C	A	C	A	?	A	A	A	A	A	A	A	A	C	C	A	G	A	A	A	C
10	Laurales	A	C	C	A	A	A	A/C	A	A/C	A	A	A	A	G	G	A	A	A	A	C	C	A	C	A	C	A	C	A	C	A	C	A	A	C	A	A	T	A	A	A	C
11	Myristicaceae	A	A	C	A	A	A	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	?	?	?	G	A	C	C	C	A	C	A	A	A	C	C	G	A	A	A	A
12	Annonales	A	C	C	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	C	C	A	A	A	G	C	C	C	C	A	A	A	C	A	A	A	C	A	A	A	C
13	Magnoliales	A	C	C	A	A	A	C	C	C	A	G	A	A	A	A	A	A	A	A	C	C	A	A	A	G	A	C	C	A	A	A	A	A	C	C	C	A	A	A	A	C
14	Ranunculidae	C	A	A	A	A	A	A	C	G	C	A	A	A	A	A/T	A	A	A	A	A	C	A	A	G	C	A	A	C	A	A	A	A	A	C	C	G	A	A	C	
15	Eupteleaceae	A	A	A	A	A	A	C	C	G	C	C	A	A	A	G	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	G	A	A	A	C
16	Platanaceae	A	C	A	C	A	A	C	C	G	C	A	A	A	A	G	G	A	A	A	A	C	?	?	?	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A	
17	Nelumbonaceae	A	A	A	A	A	A	C	C	G	C	G	C	G	A	A	A	A	A	C	A	A	C	?	?	C	A	A	C	A	A	A	A	A	A	?	A	A	A	A	A	A
18	Trochodendrales	A	A	A	A	A	A	C	C	G	C	A	A	C	A	G	G	A	A	A	A	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	G	T	A	?
19	Proteaceae	A	A	A	A	C	A	C	C	G	C	A	C	A	C	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	G	G	A	C
20	Buxaceae	A	A	A	A	A	A	C	C	T	A	A	A	A	G	C	A	A	A	A	A	C	A	A	A	C	C	A	A	A	A	C	A	C	C	A	A	A	A	A	A	
21	Sabiaceae	A	A	A	A	A	A	C	?	G	G	C	A	A	A	G	G	C	A	A	?	G	?	?	?	?	?	A	?	?	A	?	?	?	?	?	?	A	A	A	A	
22	Didymelaceae	A	A	A	A	A	A	?	?	G	C	C	A	A	A	G	G	A	?	?	?	?	?	?	?	?	?	A	?	?	A	?	?	?	?	?	?	?	?	?	?	?
23	Myrothamnaceae	A	A	A	A	A	A	C	C	G	C	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A	A	A	A	?	?	A	?	A	?	?	?	?	?	?	?	?
24	Berberidopsidaceae	A	A	?	A	A	A	?	?	G	C	?	A	A	A	A	A	A	A	A	A	?	?	?	?	A	C	A	A	A	A	A	A	C	A	C	C	C	A	A	C	
25	Gunneraceae	A	A	A	A	A	A	C	C	G	C	G	A	A	A	G	C	A	A	A	A	C	?	?	?	A	A	A	?	?	A	A	A	?	A	A	A	A	A	A	A	A	
26	Rhabdodendraceae	A	C	?	?	A	?	?	?	G	G	C	A	A	A	G	C	C	A	A	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?
27	Simmondsiaceae	A	A	A	A	A	A	?	?	G	C	G	A	A	A	C	A	A	A	?	A	C	A	A	A	G	A	A	A	A	A	C	C	A	C	A	A	A	A	A	A
28	Caryophyllales	C	C	A	C	C	A	C	C	G/T	A/C	A	A	C	A	C	A	A	A	C	A	C	A	A	G	C	A	A	A	A	A/C	A	C	A	C	A	A	A	A	A	C
29	Asteropeiaceae	A	A	?	?	A	A	?	?	G	C	G	A	A	A	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
30	Plumbaginaceae	A	A	A	A	A	A	?	C	G	C	G	A	A	A	C	A	A	?	A	A	C	A	A	A	A	A	?	?	?	A	?	?	?	?	?	?	?	A	A	A	A
31	Polygonaceae	A	C	C	A	A	C	C	C	G	C	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	A	C	A	C	A	A	?	C	A	A	A	A	A	A	C
32	Dioncophyllaceae	?	A	C	A	A	A	?	G	C	G	A	A	A	C	A	A	A	A	A	A	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
33	Ancistrocladaceae	A	?	C	A	A	C	?	?	G	C	G	A	A	A	C	A	A	A	?	A	C	?	?	?	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A
34	Nepenthaceae	A	A	A	C	A	A	?	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	A	A	A	A	A
35	Droseraceae	A	C	A	A	A	A	C	C	G	C	C	A	A	A	C	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C
36	Tamaricaceae	A	A	A	A	A	A	C	C	G	C	A	A	C	C	A	A	A	A	C	A	A	A	A	A	G	A	A	A	A	A	C	C	A	A	A	C	A	A	A	A	A
37	Frankeniaceae	A	C	A	A	A	A	C	C	G	C	C	A	A	A	A	A	A	A	C	A	A	A	A	A	G	A	A	A	A	A	C	C	A	A	A	C	A	A	A	A	A
38	Hamamelidales	A	C	A	A	A	A	A	C	G	C	A	A	C	A	G	C	A	A	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	?
39	Dilleniaceae	A	C	C	A	A	A	C	C	G	C	A	A	A	G	G	A	A	A	A	A	A	A	C	C	A	A	A	C	A	A	A	C	A	A	C	C	C	A	A	C	A
40	Vitaceae	A	A	A	A	C	A	C	C	G	G	C	C	A	C	G	G	A	A	A	A	A	A	A	A	G	A	A	C	A	A	A	A	A	A	C	C	C	A	A	C	
41	Eucryphiaceae	A	A	A	A	A	A	?	?	G	C	A	A	A	A	G	G	A	A	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?
42	Brunelliaceae	A	A	A	A	A	A	?	?	G	G	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	C	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?
43	Cunoniales	A	C	C	A	A	A	C	C	G	C	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	A	A	A	A	?	?	?	?	?	?	?	?	?	?	C
44	Paeoniaceae	A	A	A	A	A	A	C	C	G	G	G	A	A	A	G	G	A	A	A	A	A	A	A	A	C	C	A	C	A	A	C	A	A	A	C	A	A	A	A	A	C
45	Cephalotaceae	A	A	A	A	A	A	?	?	G	G	A	C	A	C	G	G	A	A	A	A	?	?	?	?	A	A	A	?	?	A	A	?	A	A	A	A	A	A	A	A	C
46	Crassulaceae	A	C	A	A	C	A	C	C	G	G	C	A	A	C	T	A	A	A	A	A	C	C	A	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	C
47	Saxifragales s. str.	A	A	A	A	A	C	C	C	G	G	A	A	A	A	A	A	A	A	A	A	C	C	A	A	?	A	C	A	A	C	A	?	A	A	A	A	A	A	A	A	C
48	Staphyleaceae	A	A	A	A	A	C	C	C	G	G	C	A	A	A	G	G	A	A	A	A	A	?	?	?	C	A	A	A	A	A	C	A	C	C	A	A	A	A	A	A	C
49	Elaeagnaceae	A	C	C	A	A	A	C	C	C	G	G	C	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	C
50	Rosaceae	A	C	A	A	A	A	C	C	?	G	G	A	C	A	C	T	A	A	A	A	A	C	?	?	C	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	C
51	Rhamnaceae	A	C	A	A	A	A	C	C	G	G	A	A	A	C	A	A	A	A	A	A	A	A	A	A	G	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	C
52	Fagaceae	A	C	C	C	A	C	C	C	G	C	A	A	C	C	C	A	A	A	A	A	A	A	A	A	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
53	Cucurbitales	A	A	C	A	C	C	C	C	G	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	G	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C
54	Coriariaceae	A	A	A	A	A	A	C	C	G	G	C	C	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	C
55	Urticales	C	A	C	A	C	C	C	C	G	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C

Appendix 1. Continued.

dill.mat5	5	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
		endc	endc	emb	emb	susp	grow	disp	anor	phlo	wedc	inter	corti	scler	woo	fiber	fiber	tracl	librif	type	hom	rays	stor	vesti	vess	end	vess	vess	vess	denc	leaf	leaf	stipu	glan	leaf	stor	epid	muci	palm	cras	leaf
1	Ceratophyllaceae	T	A	G	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A	?	?	?	A	A	?	A	?	?	A	A	A	A	C	A	A	G	A	A	C	A	A
2	Chloranthaceae	A	A	A	A	A	A	?	A	?	?	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	G	A	A/C	C	C	A	A	G	A	A	A	A	C
3	Nymphaeaceae	?	A	A	A	A	C	C	A	A	A	A	?	?	?	A	A	C	A	?	?	?	A	A	?	A	A	?	G	A	?	A	C	A	A	G	A	A	C	A	A
4	Amborellaceae	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	G	A	A	A	A	A	A	A	A	?	A	A	C
5	Austrobaileyaceae	C	A	A	A	A	C	A	A	?	A	A	A	C	A	A	A	C	A	A	A	A	A	A	G	C	A	A	A	A	A	C	A	A	A	A	A	?	A	A	A
6	Illiciales	A	A	A	A	A	C	A	A	?	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	C	A	A	C
7	Winterales	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	G	A	C	A	A	A	A	A	C	C	A	A	A
8	Monocotyledons	A	A	A	A	C	A/C	C	C	A	A	A	C	C	G	A	A	A	A	T	A	A	A	A	?	C	A	G	C	A	?	A	A	A	A	A	A	A	C	A	A
9	Aristolochianae	A	A	A	A	A	C	C	A	A	A	A	A	C	A	A	A	?	A	A	A	A	C	A	C	G	A	A	A	A	G	A	C	A	A	G	A	A	C	A	A
10	Laurales	A	A	C	A	A	A/C	A	A	A	A	A	C	C	A	A	A	C	A	C	A	A	C	A	C	C	A	G	A	C	A	C	A	A	A	A	A	A	C	A	C
11	Myristicaceae	A	A	A	A	A	A	A	A	C	C	C	A	C	C	A	A	A	C	?	?	?	A	A	C	C	?	G	C	A	C	A	C	A	A	A	A	A	A	A	A
12	Annonales	A	A	A	A	A	A/C	A	A	C	C	A	A	C	A	A	A	A	A	A	A	A	C	A	C	C	A	A	C	C	G	A	A	A	A	A	C	A	A	A	A
13	Magnoliales	A	A	A	A	A	A	A	A	C	C	A	C	C	G	A	A	C	A	A	A	A	A	A	C	C	?	A	A	A	G	A	C	A	A	A	C	A	A	A	A
14	Ranunculidae	A	A	A	A	A	C	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	C	A	C	C	A	G	A	C	C	A	C	A	A/C	C/G	A	A	C	C	C
15	Eupteleaceae	A	A	A	A	A	A	A	A	A	A	A	A	C	G	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	A	G	A	A	A	A	C
16	Platanaceae	A	A	G	A	A	A	A	A	?	C	A	A	C	A	A	A	C	A	T	C	A	A	A	C	G	A	A	C	A	G	A	C	A	A	G	A	A	C	C	C
17	Nelumbonaceae	G	A	T	A	A	C	?	A	A	A	A	A	A	?	A	A	C	A	?	?	?	A	A	T	C	A	?	A	A	?	G	C	A	A	G	A	A	C	A	A
18	Trochodendrales	A	C	A	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	A	A	A	G	A	G	A	C	A	A	A	A	?	C	C	C
19	Proteaceae	A	A/C	G	A	A	A	A	A	C	C	A	C	C	G	A	A	C	A	C	A	A	A	A	T	G	A	C	A	A	C	A	A	A	A	A	A	A	A/C	C	C
20	Buxaceae	A	A	C	A	A	A	A	A	A	?	A	C	C	C	C	A	C	A	A	A	A	A	A	C	C	A	C	A	A	C	A	A	A	A	C	A	A	C	C	C
21	Sabiaceae	?	A	G	C	A	A/C	A	A	?	C	A	A	C	A	A	A	C	A	C	A	A	A	A	C	C	A	A	A	A	C	A	A	A	A/C	G	A	?	A	C	C
22	Didymelaceae	?	?	C	A	A	A	A	A	?	?	A	?	?	A	A	A	C	A	A	A	A	A	A	G	C	A	?	?	?	?	A	A	A	A	C	?	?	A	?	A
23	Myrothamnaceae	A	A	C	A	A	A	A	A	?	?	A	A	?	A	A	A	C	A	T	A	C	A	A	C	C	A	A	A	A	C	C	C	A	A	G	A	A	C	C	C
24	Berberidopsidaceae	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	G	C	A	A	A	A	?	A	C	A	A	C	A	?	C	A	C
25	Gunneraceae	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	?	?	?	?	A	?	?	T	?	?	?	?	?	A	C	A	A	G	A	A	C	C	C
26	Rhabdodendraceae	?	?	T	C	A	?	A	C	A	A	C	A	C	A	A	A	?	A	A	A	A	A	?	C	T	C	G	A	A	G	A	C	A	A	G	C	A	A	?	A
27	Simmondsiaceae	?	?	G	A	A	A	A	C	A	A	C	A	C	A	A	A	C	A	T	A	C	A	A	T	T	?	G	A	A	A	C	A	A	A	G	A	A	A	A	A
28	Caryophyllales	A	A	G	C	C	A	A	C	A	A	C	A	C	A	A	A	A	C	G	A	A	C	A	T	G	G	G	C	A	G	A	C	A	A	A/G	C	A	C	A	A
29	Asteropeiaceae	?	?	G	C	A	C	A	?	?	?	?	?	?	G	C	A	A	A	T	A	C	A	A	T	T	C	G	A	A	?	A	A	A	A	G	?	?	A	A	C
30	Plumbaginaceae	C	A	C	A	A	A	A	C	A	A	C	C	C	A	A	C	A	C	G	A	A	A	A	T	T	?	?	C	A	C	A	C	A	A	A/G	A	A	A	A	A
31	Polygonaceae	C	A	C	A	A	A/C	A	A	A	A	C	C	C	A	A	A	A	A	G/T	A	A/C	C	C	T	T	?	G	A	A	?	A	C	A	A	A	A	A	C	A	A
32	Dioncophyllaceae	?	A	C	C	A	C	A	C	A	?	A	C	C	C	A	A	A	A	T	A	C	A	A	T	T	G	G	A	A	?	A	A	A	A	C	?	?	A	A	A
33	Ancistrocladaceae	C	A	C	A	A	C	A	A	A	A	A	A	C	G	A	A	A	A	T	A	C	A	A	T	T	A	G	A	A	C	A	C	A	A	C	A	?	A	A	A
34	Nepenthaceae	C	?	C	A	A	C	A	A	A	A	A	C	C	?	?	A	C	A	?	?	?	A	A	?	T	G	?	?	A	?	A	A	A	A	G	A	?	A	A	A
35	Droseraceae	C	A	C	A	A	A/C	A	A	A	C	A	A	A	G	A	A	C	A	T	A	C	A	A	T	T	C	C	A	A	C	A	C	A	A	G	A	A	A	A	A
36	Tamaricaceae	C	A	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	C	A	T	T	C	G	A	A	?	A	A	A	A	G	A	A	A	A	A
37	Frankeniaceae	C	C	C	A	A	A	A	C	A	A	A	A	A	G	C	A	A	C	T	A	C	A	A	T	T	C	G	C	A	?	C	A	A	A	G	A	A	A	A	A
38	Hamamelidales	A	A	A	A	A	A	A	A	?	A	A	A	C	C	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	C	A	C	A	A	A/G	A	C	C	C	C
39	Dilleniaceae	A	A	A	A	A	A/C	A	A	A	A	C	A	?	C	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	C	A	C	A	A	A	A	?	A	C	C
40	Vitaceae	A	A	A	A	A	C	A	A	C	A	C	A	C	C	A	A	A	C	A	A	A	C	A	C	C	A	C	C	A	C	A	C	A	A	C	A	A	C	C	C
41	Eucryphiaceae	A	?	C	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	G	A	A	A	A	C	C	A	A	C	A	C	C	C	A	A/C	A	A	C	A	?	C
42	Brunelliaceae	?	?	C	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	C	C	A	?	C	A	C	C	C	A	A	G	A	A	A	C	C
43	Cunoniales	A	A	C	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	G	C	C	A	C	G	A	C	A	C	C
44	Paeoniaceae	A	A/C	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	C	A	A	C	A	C	A	A	A	A	G	A	?	C	C	C
45	Cephalotaceae	?	?	C	A	A	A	A	A	A	A	A	A	?	?	?	?	C	?	?	?	?	A	?	?	C	A	?	?	?	A	A	A	A	A	?	A	A	A	A	A
46	Crassulaceae	A	C	G	A	C	A	A	A	A	A	A	C	A	?	A	A	A	C	?	?	?	A	A	C	T	A	G	?	?	C	A	A	A	A	G	A	A	A	A	C
47	Saxifragales s. str.	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	?	A	C	C	A	A	A	A	C	C	A	C	A	A	C	A	C	A	A	G	A	A	C	C	C
48	Staphyleaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	C	A	G	A	A	C	C	C	A	C	G	A	C	A	A	C
49	Elaeagnaceae	G	C	G	A	A	A	A	A	C	?	A	A	C	A	A	A	C	A	C	A	A	C	A	T	T	C	G	A	A	A	A	A	A	A	G	A	A	A	A	A
50	Rosaceae	?	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	C	A	A	A	A	C	G	A	G	A	C	C	A	C	C	A/C	G	A	C	A	C	C
51	Rhamnaceae	A	A	G	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	C	A	A	C	A	C	G	A	C	C	C	C	A	C	A	A	G	A	C	A/C	C	C
52	Faganae	A	A	G	A	A	A	A	A	C	A	A	A	C	C	A	A	A	A	A	A	A	A	A	C	C	A	C	A	C	C	A	C	A	A	G	A	C	A	C	C
53	Cucurbitales	A	A	G	A	A	A	A	A	A	A	C	C	C	G	A	A	A	C	G	A	A	C	A	T	G	C	A	C	A	C	A	C	A	A	G	A	A	C	C	C
54	Connaraceae	?	A	G	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	A	A	C	A	T	T	C	A	A	A	A	C	C	A	A	C	A	A	C	A	C
55	Urticales	A	A	C	A	A	A	A	A	A	C	A	A	C	G	A	A	A	C	C	A	A	C	A	G	G	C	G	A	C	C	A	C	A	A	G	A	A	C	C	C

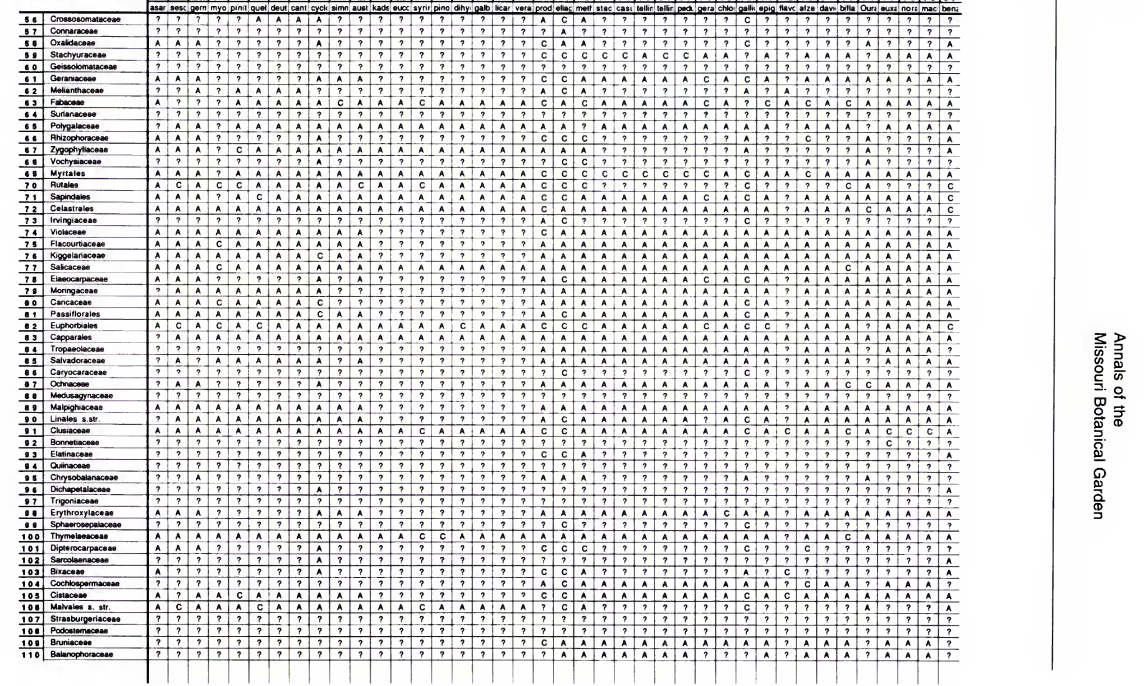
dfii.mat15	6	2 0 1	2 0 2	2 0 3	2 0 4	2 0 5	2 0 6	2 0 7	2 0 8	2 0 9	2 1 0	2 1 1	2 1 2	2 1 3	2 1 4	2 1 5	2 1 6	2 1 7	2 1 8	2 1 9	2 2 0	2 2 1	2 2 2	2 2 3	2 2 4	2 2 5	2 2 6	2 2 7	2 2 8	2 2 9	2 3 0	2 3 1	2 3 2	2 3 3	2 3 4	2 3 5	2 3 6	2 3 7	2 3 8	2 3 9	2 4 0
		salic	chlo	kran	leaf	vein	folia	elon	corti	brac	K-C	peta	num	high	trim	sepa	peta	peta	scal	peni	vani	trime	isom	cent	cent	poly	anth	inve	expo	conr	valv	nect	gync	carp	carp	carp	ovar	carp	degr	stipi	stig
1	Ceratophyllaceae	A	A	A	A	A	A	A	A	T	A	T	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	T	A	A	A	A	A	A	A	A	A
2	Chloranthaceae	A	C	A	C	A	A	A	A	C/T	A	T	A	A	A/C	A	A	A	A	C	C	C	A/C	A	A	A	A	A	A	A/C	T	C	A	A	A	A	A	A	A	A
3	Nymphaeaceae	A	A	A	C	A	A	A	C	A	A	A	C	A/T	A/C	A	A	A	A	C	A	A	A	C	A	A	C	A	A	C	C	C	A	A/C	G/T	A/T	A/T	A	A	C
4	Amborellaceae	A	C	A	A	?	A	A	?	A	A	A	C	C	C	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	T	A	A	A	T	T	C	A	A	C
5	Austrobaileyaceae	A	A	A	A	?	?	A	A	A	A	A	C	G	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	T	A	A	A	T	T	G	A	A	C
6	Illiciales	A	A	A	A	A	A	C	A	A	A	A	C	T	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	T	A	A	A	T	T	T	A	A	A	C
7	Winterales	A	A	A	C	A	A	C	A	A	A	A	C	A	C	A	A	A	A	C	A	A	A	C	A	C	A	A	A	C	T	A	A	A	T	T	C	A	A	C	C
8	Monocotyledons	A	A	A	A	A	A	C	A	A	A	A	C	A	C	A	A	A	A	A	G	C	C	A	A	C	A	A	A	T	A	A	C	C	G	A	A	A	C	A	?
9	Aristolochienae	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	G	A/C	C	A	C	C	A	A	A	T	A	C	C	A	C	G	A	A	A	C	A	?
1 0	Laurales	A	C	A	C	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	A	C	A	C	A	A	A	T	C	C	A	A	T	T	G	A	A	A	C	A
1 1	Myristicaceae	A	A	A	?	A	A	A	C	A	A	A	C	A	C	C	C	A	A	A	A	C	A	A	A	C	A	A	A	T	A	A	C	A	A	A	A	A	A	A	C
1 2	Annonales	A	A	A	C	A	A	C	C	A	A	A	C	A	C	A	A	A	A	C	A	C	A	C	A	C	A	C	A	A	C	T	C	A	A	T	T	T	A	A	C	C
1 3	Magnoliales	A	A	A	C	C	C	C	C	A	A	A	C	C	C	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	C	T	C	A	A	T	T	T	A	A	C	C
1 4	Ranunculidae	A	C	C	C	A	A	C	C	A	A	A	C	T	C	A	G	A	A	A	A	C	C	C	A	C	C	A	A	A	C	A	A	G/T	A/T	A/T	A	A	C	C
1 5	Eupteleaceae	A	?	A	A	A	A	?	C	A	T	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	T	T	G	A	A	C	C
1 6	Platanaceae	A	A	A	A	A	A	A	C	A	A	A	C	C	C	A	A	T	A	A	A	C	C	C	A	A	A	A	A	A	T	C	A	A	T	T	C	A	A	C	C
1 7	Nelumbonaceae	A	A	A	A	A	C	C	A	A	A	C	T	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	C	A	A	A	T	T	T	A	A	A	A	A
1 8	Trochodendrales	A	C	A	C	A	A	C	T	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	C	A	A	A	T	T	G	A	C	A	A	A
1 9	Proteaceae	A	A	A	C	C	C	A	A	A	A	G	G	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	A	C	C	A	A	A	A	A	C	A	A
2 0	Buxaceae	A	A	A	A	A	A	A	G	A	T	A	A	A	A	A	A	A	A	A	C	A	C	A	A	C	C	A	A	C	A	A	C	G	A	A	A	C	A	A	C
2 1	Sabiaceae	A	A	A	?	?	?	A	?	A	C	A	T	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	A	C	C/G	A/C	A	A	A	C	A	A	A
2 2	Didymelaceae	A	A	A	C	A	A	A	?	G	A	T	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	?
2 3	Myrothamnaceae	A	A	A	A	A	A	A	?	G	A	T	A	A	A	A	A	A	A	A	A	A/C	A	A/C	?	A	A	A	A	A	C	A	A	C	T	C	A	A	C	A	C
2 4	Berberidopsidaceae	A	A	A	A	?	?	A	?	A	A	A	C	G	A	A	A	A	A	A	A	A	A	A	?	?	A	A	A	A	C	A	C	A	G/T	A/G	A	A	T	C	A	A
2 5	Gunneraceae	A	A	A	A	A	A	A	C	?	G	A	A	A	C	A	A	A	C/G	A	A/C	A	?	A	A	A	A	A	A	A	C	A	A	C	C	A	A	A	G	A	A	A
2 6	Rhabdodendraceae	A	A	?	C	A	A	A	?	A	C	A	T	A	A	C	G	A	A	A	A	A	A	C	?	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	A
2 7	Simmondsiaceae	A	A	A	A	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	A	A	A	A	A	C	G	A	A	A	G	A	A	A	A
2 8	Caryophyllales	A	A	C	A	C	C	A	C	A	A	A	C	T	A	A	A	A	A	A	A	C/G	A	C	A	A	C	C	C	A	A	C	A	C	C	G/T	A/G	A	A	G	A	A
2 9	Asteropeiaceae	?	A	?	C	A	A	A	?	A	C	A	T	A	A	A	G	A	A	A	A	A	A	A	?	?	A	A	A	A	A	?	A	A	G	A	A	A	G	A	A
3 0	Plumbaginaceae	A	A	A	C	C	C	A	A	A	C	C	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	A	A	C	T	G	A	A	G	A	A	A
3 1	Polygonaceae	A	A	A	A	A	A	A	?	A	A	A	C	A	C	A	A	A	A	A	G	A	C	C	A	C	C	A	A	A	A	A	C	C	G	A	A	A	G	A	A
3 2	Dioncophyllaceae	A	A	?	?	?	?	A	?	A	C	C	T	A	A	C	G	A	A	A	G	A	C	?	?	A	A	A	A	A	C	A	A	C	C/T	G	A	A	G	A	A	A
3 3	Ancistrocladaceae	A	A	A	A	A	A	A	?	A	C	C	T	A	A	C	G	A	A	A	G	A	C	A	A	A	C	A	A	?	A	A	C	G	A	A	A	T	A	A	A
3 4	Nepenthaceae	A	A	A	C	A	A	C	A	?	A	A	A	G	A	A	A	A	A	A	A	A/G	A	A/C	?	?	C	C	A	A	A	A	A	C	T	C	A	A	T	A	A	A
3 5	Droseraceae	A	A	A	A	A	A	A	C	C	C	T	A	A	A	G	A	A	A	A	A	A/C	A	A/C	?	?	A	A	A	A	A	A	A	C	A	C	A	A	G	A	A	A
3 6	Tamaricaceae	A	A	A	C	C	C	A	A	A	C	A	T	A	A	A	G	A	C	A	G	A	C	A	C	A	C	A	A	A	A	A	C	C	T	G	A	C	G	A	A	A
3 7	Frankeniaceae	A	A	A	C	A	A	A	A	A	C	A	C	C	A	C	T	A	C	A	A	A	A	?	?	A	C	A	A	A	A	A	C	G	A	A	G	G	A	A	A	A
3 8	Hamamelidales	A	A	A	C	C	A	C	A	T	A	T	T	A	A	A	A	A	A	A	A/C	A	A/G	A/C	A/C	A	A	A	A	C	C	A	A	C	A	A	A	A	A	A	C
3 9	Dilleniaceae	A	A	A	C	C	C	A	A	A	C	A	T	A	A	A	G	A	A	A	A	A	A	A	C	A	A/C	A	A	A	C	A	A	C	T	T	G	A	A	A	A	A
4 0	Vitaceae	A	A	A	?	A	A	A	A	A	C	G	T	A	A	C	G	A	A	A	T	A	A	A	A	A	C	A	A	C	A	C	C	C	C/T	A/T	A/C	A	T	A	A	A
4 1	Eucryphiaceae	A	A	A	A	A	A	C	?	A	C	A	G	A	A	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	T	T	G	C	C	A	A	A
4 2	Brunelliaceae	A	A	A	A	A	A	A	A	A	C	A	G	T	A	A	A	A	A	A	G	A	C	?	A	A	A	A	A	C	A	C	C	C	T	T	G	A	C	A	A	A
4 3	Cunoniales	A	A	A	C	C	A	A	?	A	C	A	T	A	A	A	A/G	A	A	A	G	A	C	C	?	A	C	A	A	C	A	C	C	C	C/T	A/G	A	A	C	A	A	A
4 4	Paeoniaceae	A	A	A	?	A	A	A	C	A	A	A	T	A	A	A	G/T	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	A	C	A	T	T	G	A	A	A	A
4 5	Cephalotaceae	A	A	A	A	A	A	A	?	A	A	G	C	C	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	C	A	C	C	T	T	C	A	A	A	A
4 6	Crassulaceae	A	A	A	A	A	A	A	A	A	C	G	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	C	A	A	C	T	G	A	A	C	A	A
4 7	Saxifragales s. str.	A	A	A	A	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	C	A	C	C	T	G	A	A	C	A	A
4 8	Staphyleaceae	A	A	A	A	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	C	A	A	C	G	A	A	A	G	A	A
4 9	Elaeagnaceae	A	A	A	A	A	A	A	A	A	A	G	T	A	A	A	A	A	A	A	G/T	A	C	A	A	A	C	A	A	A	C	A	A	C	C	A	A	A	G	A	A
5 0	Rosaceae	A	A	A	A	A	C	A	A	A	C	A	T	A	A	A	G	A	A	A	A	A	A	C	A	A	C	A	A	A	C	A	C	C	T	T	G	A	A	A	A
5 1	Rhamnaceae	A	A	A	C	A	A	A	A	A	C	T	T	A	A	A	G	A	A	A	T	A	C	A	A	A	C	A	A	A	C	A	C	C	G	A	A	A	G	A	A
5 2	Fagaceae	A	A	A	?	A	C	A	A	A	A	A	C	C	A	A	A	A	A	A	A/C	A	A/C	A	A	A	A	A	A	A	A	A	A	A	T	A	A	A	G	A	A	C
5 3	Cucurbitales	A	A	A	C	A	A	A	A	A	C	A	C	C	A	A	G/T	A	A	A	C	A	C	A	A	A	A	A	A	A	C	A	C	C	C	T	T	C	A	G	A	A
5 4	Coriariaceae	A	A	A	A	A	A	A	?	A	C	G	T	A	A	A	G	A	A	A	G	A	C	A	A	A	A	A	A	A	C	A	A	C	C	T	G	A	A	A	A	A
5 5	Urticales	A	A	A	A	A	A	A	A	A	A	A	T	A	A	A	A	A	A	A	C/G	A	C	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	G	A	A	A

Appendix 1. Continued.

	dill.mat5	7	2 4 1	2 4 2	2 4 3	2 4 4	2 4 5	2 4 6	2 4 7	2 4 8	2 4 9	2 5 0	2 5 1	2 5 2
			plac	diffu	stigr	ovar	ovuk	ovui	micr	obtu	seec	fruit	type	cent
1	Ceratophyllaceae		A	A	C	A	C	A	G	A	C	C	T	A
2	Chloranthaceae		A	A	A	A	C	A	A/C	A	C	C	T	A
3	Nymphaeaceae		A	C	C	A	T	A/C	C	A	T	A	A	A
4	Amborellaceae		A	A	A	A	C	A	A	A	C	C	T	A
5	Austrobaileyaceae		A	A	C	A	T	C	C	A	T	C	T	A
6	Illiciales		A	A	C	A	T	C	A	A	G	A	A	A
7	Winterales		A	A	C	A	T	C	C	A	T	C	T	A
8	Monocotyledons		A	A	C	A	T	A/C	?	?	T	A	A	A
9	Aristolochiaeae		A	A	C	A	T	A/C	C	?	T	A	A	A
10	Laurales		A	A	C	A	C/G	C	C	C	C	C	T	A
11	Myristicaceae		A	A	C	A	C	C	C	A	C	A	G	A
12	Aimoniales		A	A	C	A	T	C	C	C	T	C	T	A
13	Magnoliales		A	A	C	A	T	C	A/C	C	T	A	A	A
14	Ranunculidae		A	A/C	C	A	T	A/C	C	A	T	A	A	A
15	Eupteleaceae		A	A	C	A	T	C	A	A	G	C	T	A
16	Platanaceae		A	A	C	A	C	A	C	A	C	A	A	A
17	Nelumbonaceae		A	A	A	A	C	C	C	C	C	C	T	A
18	Trochodendrales		A	A	C	A	T	C	A	A	T	A	A	A
19	Proteaceae		A	A	A	A	T	A/C	C	C	T	A	A	A
20	Buxaceae		G	A	C	A	G	C	A	C	G	A	C	A
21	Sabiaceae		G	A	A	A	G	?	G	A	A	C	T	A
22	Didymelaceae		A	A	C	A	C	C	A	?	C	C	T	A
23	Myrothamnaceae		G	A	C	A	T	C	C	A	T	A	A	A
24	Berberidopsidaceae		T	A	A	A	T	C	C	A	T	C	T	A
25	Gunneraceae		C	A	A	A	A	C	C	A	A	C	T	A
26	Rhabdodendraceae		A	A	C	?	G	C	G	?	C	C	T	A
27	Simmondsiaceae		G	A	A	A	C	C	?	A	A	A	C	A
28	Caryophyllales		G	A	C	A	T	C	C	C	T	A	C	A
29	Asteropeiaceae		T	A	A	?	T	?	?	?	?	A	C	?
30	Plumbaginaceae		G	A	A	A	A	C	C	C	A	A	C	A
31	Polygonaceae		G	A	C	A	A	A	C	A	A	C	T	A
32	Dioncophyllaceae		T	A	A	A	T	C	C	A	G	A	C	A
33	Ancistrocladaceae		G	A	A	C	A	C	?	A	A	C	T	A
34	Nepenthaceae		G	A	A	A	T	C	C	A	T	A	C	A
35	Droseraceae		G/T	A	C	A	T	C	C	A	T	A	C	A
36	Tamaricaceae		T	A	C	A	T	C	C	A	T	A	C	A
37	Frankeniaceae		T	A	C	A	T	C	C	A	T	A	C	A
38	Hamamelidales		A	A	C	A	C/T	C	A	A	A	C/T	A	A
39	Dilleniaceae		A	A	A	A	T	C	A	A	T	A	A	A
40	Vitaceae		T	A	A	A	G	C	C	C	G	C	T	A
41	Eucryphiaceae		G	A	A	A	T	C	A	?	T	A	A	C
42	Brunelliaceae		A	A	A	A	G	C	?	A	G	A	A	A
43	Cunoniales		A	A	A	A	T	C	A	A	T	A	A	A
44	Paeoniaceae		A	A	C	A	T	C	A	A	T	A	A	A
45	Cephalotaceae		A	A	?	A	G	C	C	A	C	A	A	A
46	Crassulaceae		A	A	A	A	T	C	A	A	T	A	A	A
47	Saxifragales s. str.		A	G	A	A	T	C	C	C	T	A	A	A
48	Staphyleaceae		G	A	A	A	T	C	A	A	T	A	C	A
49	Elaeagnaceae		G	A	A	A	C	C	A	C	C	T	C	A
50	Rosaceae		A	A	A	A	T	C	A	C	T	A	A	A
51	Rhamnaceae		G	A	A	A	G	C	C	A	C	A	C	A
52	Fagaceae		G	A	C	C	G	A/C	A	A	C	C	T	A
53	Cucurbitales		T	A	A	C	T	C	A	C	T	A	C	A
54	Coriariaceae		A	A	A	A	C	C	C	A	C	C	T	A
55	Urticales		C	A	C	A	C	C	A/C	C	A	C	T	A

Appendix 1. Continued.

dill.mat6	8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
		sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	Al a	amc	dhuu	prot	trigh	taxij	proa	hete	card	valin	linal	lotal	linal	neol	tyro	prun	sam	zier	hold	gluc	dihy	acet	eleo	myri
66	Crossosomataceae	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
67	Connaraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
68	Oxalidaceae	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
69	Stachyuraceae	?	?	?	?	A	A	A	?	?	?	A	A	A	A	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
70	Geissolomataceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
71	Geraniaceae	?	?	?	?	?	?	?	A	A	C	?	?	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
72	Melianthaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
73	Fabaceae	?	A	A	?	?	?	?	?	A	A	C	?	?	?	?	?	?	A	C	A	A	A	A	C	C	A	A	C	C	C	A	A	C	C	C	C	A	C	A	A	A
74	Surianaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
75	Polygalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
76	Rhizophoraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
77	Zygophyllaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?	?	?
78	Vochysiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
79	Myrtales	?	?	?	?	?	?	?	A	C	C	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A
80	Rutales	?	?	?	?	?	?	?	C	C	C	?	?	?	?	?	?	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	C	A	A	C	C	A
81	Sapindales	?	?	?	?	?	?	?	A	C	C	?	?	?	?	?	?	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	C	C	A
82	Celastrales	?	?	?	?	?	?	?	A	A	C	?	A	A	A	A	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A
83	Irvingiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?
84	Violaceae	?	?	?	?	A	A	C	C	A	C	C	A	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A
85	Flacourtiaceae	?	?	?	?	A	C	C	C	C	C	C	A	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
86	Kiggelariaceae	?	?	?	?	C	C	C	?	?	?	A	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
87	Salicaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A
88	Elaeocarpaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	C	?	?	A	C	A	A
89	Moringaceae	?	?	?	?	A	A	A	?	?	?	A	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	?
90	Caricaceae	?	?	?	?	A	A	A	?	?	?	A	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	C	A	A	A
91	Passiflorales	?	?	?	?	C	C	C	C	C	C	C	A	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	A	A	A	A
92	Euphorbiales	?	?	?	?	A	A	C	C	C	C	?	A	?	?	?	?	C	A	C	A	C	C	A	A	A	C	C	A	A	A	A	A	A	A	A	A	C	C	A	C	A
93	Capparales	?	?	?	?	A	A	C	A	A	A	A	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	?
94	Tropaeolaceae	?	?	?	?	A	A	A	C	C	C	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A
95	Salvadoraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A
96	Caricaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
97	Ochnaceae	?	?	?	?	A	A	A	?	?	?	A	A	A	A	A	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
98	Medusagynaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
99	Malpighiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
100	Linales s.str.	?	?	?	?	?	?	?	C	C	C	?	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	A	A	C	C	C	A	A	A	?
101	Clusiaceae	?	?	?	?	A	A	A	?	?	?	A	A	A	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
102	Bonnetiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
103	Elatinaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
104	Quiinaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
105	Chrysobalanaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?
106	Dichapetalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	A	?
107	Trigoniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
108	Erythroxylaceae	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
109	Sphaerosepalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
110	Thymelaeaceae	?	?	?	?	?	?	?	C	C	C	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	C
111	Dipterocarpaceae	?	?	?	?	A	A	A	?	?	?	A	A	A	A	A	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	A	?	A	A
112	Sarcolaenaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	?
113	Bixaceae	?	?	?	?	A	A	A	?	?	?	A	?	?	?	?	?	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A
114	Cochlospermaceae	?	?	?	?	?	A	A	A	?	?	?	A	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?
115	Cistaceae	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
116	Malvales s. str.	?	?	?	?	A	A	A	A	A	A	A	?	?	?	?	?	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A
117	Strasburgeriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
118	Podostemaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
119	Bruniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
120	Balanophoraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?


dfll.mat5 9
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
asar besc gern myo pinn quel deut cant cycl simn aust kade euoc syri pino dihy galb licar vera prod ellac metf stac casi tellr tellir peck gera chlo gelh epig filvc elze dasy bflla Ouri euzu norz mac benu
56 Crossosomataceae
57 Connaraceae
58 Oxalidaceae
59 Staphyuraceae
60 Geissolomataceae
61 Geraniaceae
62 Meliaanthaceae
63 Fabaceae
64 Surianaceae
65 Polygalaceae
66 Rhizophoraceae
67 Zygophyllaceae
68 Vochysiaceae
69 Myrtales
70 Rutales
71 Sapindales
72 Celastrales
73 Irvingiaceae
74 Violaceae
75 Flacourtiaceae
76 Kiggelariaceae
77 Salicaceae
78 Elaeocarpaceae
79 Moringaceae
80 Caricaceae
81 Passiflorales
82 Euphorbiales
83 Capparales
84 Tropaeolaceae
85 Salvadoraceae
86 Caryocaraceae
87 Ochnaceae
88 Medusagynaceae
89 Malpighiaceae
90 Linales s.str.
91 Clusiaceae
92 Bonnetiaceae
93 Elatinaceae
94 Quiinaceae
95 Chrysobalanaceae
96 Dichapetalaceae
97 Trigoniaceae
98 Erythroxylaceae
99 Sphaerosepalaceae
100 Thymeleaceae
101 Dipterocarpaceae
102 Sarcolaenaceae
103 Bixaceae
104 Cochlospermaceae
105 Cistaceae
106 Malvales s. str.
107 Strasburgeriaceae
108 Podostemaceae
109 Bruniaceae
110 Balanophoraceae

Appendix 1. Continued.

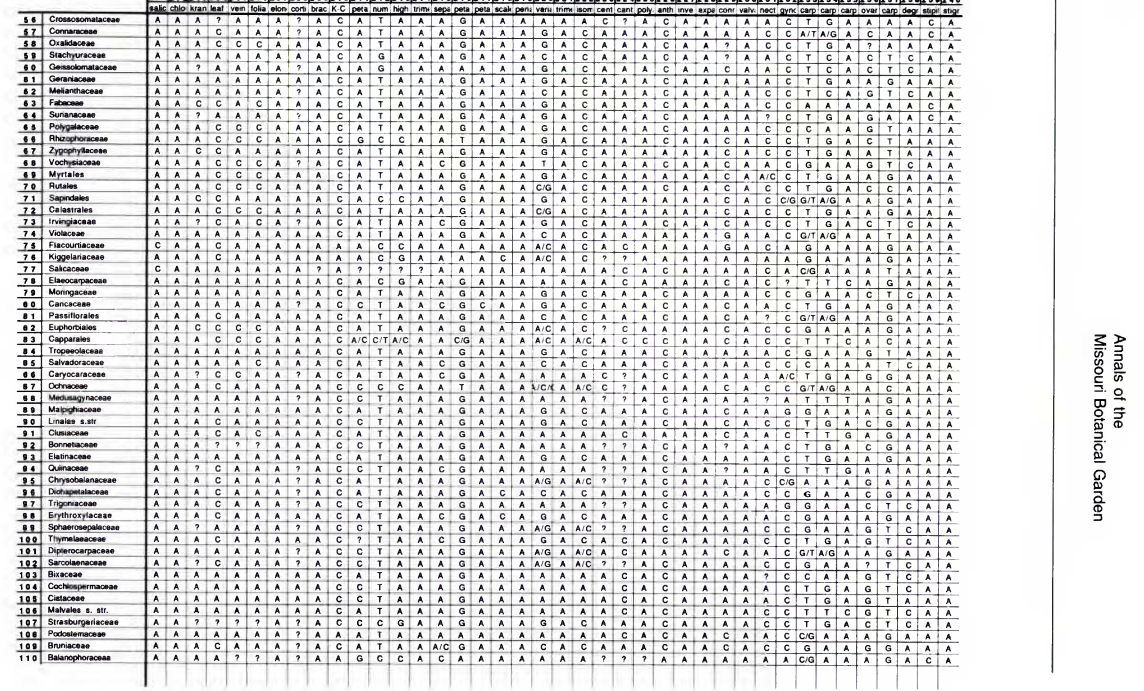
dill.mat6	10	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
		rosm	angr	lirio	prot	anci	cam	indo	indo	secr	corn	olea	arjun	dam	cucu	nagr	arbu	nagr	rapa	plum	dros	anth	pher	anth	actr	nitro	chro	swer	atrat	rod	epic	SIOC	oxal	elon	asar	crys	siphi	myrr	oil c	muc	rean
56	Crossosomataceae	?	?	?	?	?	A	?	A	A	?	A	A	A	?	?	?	?	?	?	?	?	?	?	A	?	C	A	A	A	A	A	C	A	A	C	A	A	A	C	C
57	Connaraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	A	A	A	A	?	A	C	A	A	A	C	C	A	A	C	A	A	A	A	C	C
58	Oxalidaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	?	?	?	A	A	A	C	A	A	A	A	A	A
59	Stachyuraceae	A	A	A	A	A	A	A	?	?	?	?	?	?	?	A	A	A	A	A	A	A	?	A	A	A	A	C	A	C	C	A	C	A	A	A	A	A	A	A	A
60	Geissolomataceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	C	A	A	A	A	C	A
61	Geraniaceae	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	C	C	?	?	?	A	C	G	C	A	A	A	A	A	C
62	Melianthaceae	?	?	?	?	?	?	?	?	?	?	?	C	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	G	C	A	A	A	A	C	C
63	Fabaceae	A	A	A	A	A	A	C	A	A	A	A	C	A	C	A	A	A	A	A	A	A	C	A	A	A	A	C	C	A	?	C	C	C	G	C	A	C	A	A	C	C
64	Surianaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	?	?	?	?	A	C	A
65	Polygalaceae	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	C	C	?	?	?	A	C	A	C	A	A	A	A	A	A
66	Rhizophoraceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	A	A	?	?	?	C	C	A	C	A	A	A	A	C	A
67	Zygophyllaceae	A	A	A	A	A	A	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	C	?	?	?	A	C	C	C	A	A	A	A	C	C
68	Vochysiaceae	?	?	?	?	?	?	?	A	A	A	?	?	?	A	?	A	A	A	A	A	C	A	A	A	?	A	?	C	?	?	?	C	C	A	C	A	A	A	A	C	A
69	Myrtales	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	C	A	A	A	C	A	A	A	A	A	C	C	?	?	?	A	C	C	C	C	A	A	A	C	C
70	Rutales	A	A	C	C	A	A	C	A	A	A	?	C	C	A	A	A	C	A	A	A	C	A	C	A	A	A	C	C	?	?	?	C	C	C	C	C	A	A	A	C	C
71	Sapindales	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	?	?	?	C	C	G	C	C	C	A	A	C	C
72	Celastrales	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	?	?	?	C	C	G	C	C	A	A	A	C	A
73	Irvingiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	?	?	?	C	C	A	C	A	A	A	A	?	A
74	Violaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	A	C	?	?	?	A	C	A	C	A	A	A	A	C	C
75	Flacourtiaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	C	?	?	?	C	C	G	C	A	A	A	A	C	C
76	Kiggelariaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?	?	?	C	C	G	C	A	A	A	A	C	A
77	Salicaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	C	A	A	A	C	?	?	?	C	A	C	A	C	A	A	A	C	A
78	Elaeocarpaceae	A	A	A	A	A	A	C	A	A	A	A	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	C	C	A	C	A	C	C	G	C	A	A	A	C	A
79	Moringaceae	A	A	A	A	?	A	?	A	A	A	A	A	A	?	A	?	?	?	?	?	?	?	?	?	A	A	C	C	?	?	?	A	C	A	A	A	A	C	A	C	A
80	Caricaceae	A	A	A	A	A	A	?	A	A	?	C	A	A	A	?	?	?	?	?	?	?	?	A	?	A	A	A	C	?	?	?	A	C	A	A	A	A	A	A	A	A
81	Passiflorales	A	A	A	A	A	A	C	A	A	A	A	C	A	A	A	C	A	A	A	A	?	?	A	A	A	A	A	C	C	?	?	?	A	C	A	C	A	A	A	A	C	C
82	Euphorbiales	A	A	C	A	A	A	C	A	A	A	A	C	A	A	A	C	A	A	A	A	A	C	C	A	A	A	A	A	A/C	?	?	?	C	C	G	C	A	C	A	C	C	C
83	Capparales	A	A	A	A	A	A	C	A	A	A	A	A	A	A	C	A	A	?	?	?	?	?	A	A	A	A	C	A	?	?	?	A	C	G	C	A	C	A	C	C	A
84	Tropaeolaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	A	C	C	?	?	?	A	?	?	?	A	?	C	A	C	A
85	Salvadoraceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	A	A	A	A	C	A	C	A	A	A	A	A
86	Caryocaraceae	?	?	?	?	?	?	?	?	?	?	?	C	A	A	?	?	?	?	?	?	?	?	?	?	?	A	?	C	C	A	A	A	C	C	C	G	C	A	A	A	?
87	Ochnaceae	A	A	A	A	A	A	?	A	A	A	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	C	C	G	C	A	A	A	C	A
88	Medusagynaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	G	C	C	A	A	C	A
89	Melianthaceae	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	C	C	?	?	?	A	C	G	C	A	A	A	A	C	A
90	Linales s.str.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	C	C	?	?	?	C	C	A	C	A	A	A	A	C	A
91	Clusiaceae	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	A	A	A	A	A	A	C	C	A	A	A	C	C	G	C	A	A	A	A	C	A
92	Bonnetiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	C	A	A	C	C	C	A	?	A	?	A	A	C
93	Elatinaceae	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	A	?	?	C	A	C	A	A	A	A	A	A	C
94	Quiinaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	C	A	A	C	C	C	A	A	A	A	A	C	A
95	Chrysobalanaceae	?	?	?	?	?	?	?	?	A	?	?	?	?	?	C	?	?	?	?	?	?	?	?	A	?	?	A	A	C	C	A	A	A	C	C	A	A	A	A	A	A
96	Dichapetalaceae	A	A	A	A	?	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	A	C	A	C	A	C	A	A	A	C	A
97	Trigoniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	?	?	?	A	C	A	C	A	A	A	A	C	A
98	Erythroxylaceae	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	?	?	?	?	A	A	A	A	A	A	A	?	?	?	C	A	A	C	A	A	A	A	C	C
99	Sphaerosepalaceae	?	A	A	?	?	A	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A	A	A	?	C	G	?	A	?	A	A	C	C
100	Thymelaeaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	C	?	?	?	A	A	C	?	?	?	A	A	A	C	C
101	Dipterocarpaceae	?	?	?	?	?	?	?	A	A	C	A	A	C	A	A	A	?	?	?	?	?	C	A	?	?	A	C	?	A	A	A	C	C	A	C	A	A	A	A	C	C
102	Sarcolaenaceae	A	A	A	A	?	A	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	?	A	A	A	?	C	A	?	A	?	A	A	C	C	C
103	Bixaceae	A	A	A	A	A	A	A	A	A	?	A	C	A	A	A	?	?	?	?	?	?	?	A	?	A	C	C	A	A	A	A	C	A	?	A	?	A	A	C	C	C
104	Cochlospermaceae	?	?	?	?	?	?	?	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	A	C	A	A	A	A	A	C	C	C
105	Cistaceae	A	A	A	A	A	A	A	A	A	A	?	?	C	A	A	?	?	?	?	?	?	C	A	A	A	C	C	C	A	A	A	C	A	A	A	A	A	A	C	C
106	Malvales s. str.	A	A	A	A	A	A	A	C	C	A	A	A	A	C	C	A	A	C	A	A	A	A	A	C	A	A	C	C	A	C	A	C	C	A	C	A	C	A	A	C	C
107	Strasburgeriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	C	C	A	A	A	?	C	G	C	?	?	A	A	C
108	Podostemaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	C	?	?	?	C	C	A	C	A	A	A	A	C	C
109	Bruniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	A	A	A	C	C	A	C	C	A	A	A	A	C
110	Balanophoraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	C	A	C	A	A	A	A	A	A	A

Appendix 1. Continued.

dill.mats	11	1 2	1 3	2 2	2 3	1 2	4 1	2 5	1 2	4 2	7 1	2 8	1 2	8 3	2 9	3 1	1 3	2 1	3 3	1 4	2 6	3 5	1 3	6 1	2 7	1 3	6 2	1 4	0 1	4 1	0 2	4 1	4 3	1 4	4 1	4 5	1 4	6 1	4 7	1 4	8 1	4 9	1 6	0 1	5 1	1 5	2 1	5 3	1 5	4 1	5 5	1 5	6 1	5 7	1 5	8 1	9 1	6 0
		labic	fasc	pelt	delt	cory	plan	anth	micr	poll	type	pola	tran	tnan	angu	sacc	type	inte	inte	nucc	perit	endc	occu	occu	occu	occu	end	ar/l	pacf	sarc	rumi	axot	axot	theo	tann	mes	endc	endc	axot	axot	bixo	hypc
56	Crossosomataceae	A	?	A	A	A	A	C	C	G	G	C	A	A	A	G	G	A	A	A	A	?	A	A	A	A	?	C	A	A	A	A	?	?	?	?	?	?	A	A	A	C
57	Connaraceae	A	C	A	C	C	A	?	?	G	G	A	A	A	G	A	A	A	A	A	A	?	?	?	G	C	A	C	A	A	C	A	A	A	C	C	G	A	A	A
58	Oxalidaceae	A	A	A	A	A	A	C	C	G	C/G	C	A	A	A	G	G	A	A	G	A	A	A	A	A	C	C	A	A	A	A	C	A	A	A	C	A	G	A	A
59	Stachyuraceae	A	?	A	A	A	A	?	?	G	G	C	A	A	A	G	C	A	A	A	A	A	A	A	A	A	C	?	A	A	A	A	A	?	C	?	A	A	A	A
60	Geissolomataceae	A	?	?	?	A	?	?	?	G	G	C	A	A	A	G	C	A	A	A	?	C	A	A	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
61	Geraniaceae	A	A	A	A	A	A	C	C	G	C	C	A	A	A	G/T	A/G	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	A	A	A	C
62	Melianthaceae	A	C	A	A	C	A	C	A/C	G	G	C	A	A	A	T	A	C	A	A	A	A	A	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	C
63	Fabaceae	A	C	C	C	C	C	C	C	G	C	C	A	A	A	T	A	A	A	A	A	A	A	C	A	A	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C
64	Surianaceae	A	A	?	?	A	A	?	?	G	G	C	C	A	C	T	A	C	A	A	C	A	?	?	?	?	A	C	A	A	A	?	?	C	A	?	A	?	?	C	A	?
65	Polygalaceae	A	A	A	A	A	A	C	C	G	G	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	C	C	A	A	A	C
66	Rhizophoraceae	A	C	A	A	A	A	?	C	G	G	A	A	A	C	G	C	A	C	A	A	A	?	?	?	C	C	A	A	A	A	C	A	C	A	A	A	A	A	A	A
67	Zygophyllaceae	A	A	A	A	C	A	C	C	G	C	A	A	A	A	G	G	A	A	A	A	A	A	A	A	G	A	A	A	C	A	A	A	A	A	C	A	A	A	A	C
68	Vochysiaceae	A	C	A	A	C	A	?	?	G	G	A	A	A	C	T	A	A	A	A	A	A	?	?	?	?	A	A	A	A	C	A	A	A	?	C	A	A	A	A	C
69	Myrtales	A	C	C	C	C	C	C	C	G	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A/C	A	A	A	A	C	C	C	C	A	A	A	A	C
70	Rutales	A	C	C	A	C	C	C	C	G	G	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	C	A	A	A	A	A	C
71	Sapindales	A	C	C	A	C	C	C	C	G	C	A	C	A	C	G/T	A/G	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	C	C	A	A	A	A	C
72	Celastrales	C	C	A	A	C	A	C	C	G	G	A	A	A	A	G	G	A	C	A	A	A	C	A	A	G	C	A	A	A	A	A	A	A	A	A	A	G	A	A	C
73	Irvingiaceae	A	A	?	?	A	A	?	?	G	G	A	C	C	A	A	A	?	A	A	?	?	?	?	C	A	A	A	A	A	A	A	A	A	C	?	A	G	A	A	?
74	Violaceae	A	A	A	A	A	A	C	C	G	G	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	C	A	G	A	A	C
75	Flacourtiaceae	C	C	A	A	C	A	C	C	G	G	A	A	A	A	G	C	A	A	A	A	A	?	?	?	A	A	A	A	A	A	A	A	A	A	C	A	G	A	A	C
76	Kiggelariaceae	A	A	C	A	A	A	C	C	G	G	A	A	A	A	G	C	A	A	A	A	A	?	?	?	G	A	C	C	A	A	A	A	C	A	A	C	A	G	A	A	C
77	Salicaceae	A	A	A	A	A	A	C	?	G	G	C	A	A	A	G	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	?	A	A	A	A	C
78	Elaeocarpaceae	A	A	A	A	A	A	C	C	G	G	A	A	A	A	G	C	A	C	A	A	A	A	A	A	G	C	A	A	A	A	A	A	A	A	A	C	A	G	A	A	C
79	Moringaceae	A	A	A	A	A	A	C	C	G	G	G	A	A	A	A	A	A	A	A	A	A	A	A	A	G	A	A	A	A	A	A	A	A	A	C	?	A	A	A	C
80	Cancaceae	C	A	A	A	A	A	C	C	G	G	G	A	A	A	G	C	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	C	A	G	A	A	C
81	Passiflorales	A	C	A	A	C	A	C	C	G	G	G	A	A	A	G	C/G	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A	A	A	C	G/T	A	A	A	C
82	Euphorbiales	A/C	C	C	C	C	C	C	C	G	C	A	A	A	C	C	A	A	A	A	A	A	A	A	A	G	C	C	C	A	A	A	A	A	A	C	C	G/T	A	A	A	C
83	Capparales	A	C	C	C	C	C	C	C	G	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	A	C	A	C	A	G	A	A	C
84	Tropaeolaceae	A	A	A	A	A	A	C	C	G	G	C	A	A	A	G	G	A	A	G	A	A	?	?	?	A	A	A	A	A	A	A	A	A	?	A	?	A	A	A	C
85	Salvadoraceae	A	A	C	A	A	A	?	C	G	G	A	A	A	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	?	A	G	A	A
86	Carnivoraceae	A	A	A	A	A	A	?	?	G	G	C	A	A	A	G	G	A	A	?	A	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
87	Ochnaceae	C	A	A	A	A	A	C	C	G	G	A	A	A	A	A	A	A	A	G	A	A	?	?	?	G	A	C	A	A	A	A	A	A	C	A	C	A	G	A	A	A
88	Medusagynaceae	A	A	A	A	A	A	?	?	G	T	A	A	A	C	G	C	A	A	C	A	?	G	?	?	A	A	A	A	A	A	A	A	A	?	?	?	A	G	A	A	C
89	Malpighiaceae	A	A	A	A	C	A	C	?	G	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	G	A	A	A
90	Linales s.str.	A	C	A	A	A	A	C	C	G	G	C	C	A	A	G	G	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	G	G	A	A	C
91	Clusiaceae	A	A	A	C	A	A	C	?	G	G	C	A	A	C	A	A	A	C	A	A	A	C	A	A	G	C	A	A	A	A	A	A	A	C	C	C	A	A	C	A	C
92	Bonnetiaceae	A	A	A	A	A	A	C	C	G	G	G	A	A	A	G	C	A	A	G	A	A	?	?	?	A	C	A	A	A	A	A	A	A	?	A	A	A	A	C	A	A
93	Elatinaceae	A	C	A	A	A	A	C	C	G	G	C	A	C	A	G	G	A	A	C	A	A	?	?	?	?	A	A	A	A	A	A	A	A	C	A	A	?	A	C	A	A
94	Quinaceae	A	A	A	A	A	A	?	?	G	G	C	A	A	A	G	G	?	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
95	Chrysobalanaceae	A	C	C	A	A	C	C	C	G	C	C	A	A	A	?	?	A	C	G	A	A	?	?	?	C	A	A	A	A	A	A	A	A	?	?	C	?	A	A	A	C
96	Dichapetalaceae	A	A	A	A	A	A	?	?	G	G	A	A	A	A	G	G	A	A	G	A	A	?	?	?	C	A	A	?	?	A	A	A	C	A	A	A	A	A	A	A	C
97	Trigoniaceae	A	A	A	A	A	A	?	?	G	G	G	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	A	A	C	A	A	?	A	A	G	A	A	A	A	C
98	Erythroxylaceae	A	A	A	A	A	A	C	C	G	G	G	A	A	A	G	G	A	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	G	A	A	A
99	Sphaerosepalaceae	A	A	A	A	A	?	?	?	G	G	?	A	A	A	A	A	A	A	A	A	A	?	?	?	?	A	A	A	C	A	A	A	?	?	?	A	T	A	A	?
100	Thymelaeaceae	A	C	A	A	C	A	C	C	G	G	C	C	A	C	C	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	T	A	A	C	C
101	Dipterocarpaceae	A	C	C	A	A	A	C	C	?	G	C	C	A	A	A	G	G	A	A	A	A	A	A	A	A	G	C	A	A	A	A	A	A	?	A	A	T	A	C	C
102	Sarcolaenaceae	A	C	C	A	C	C	?	?	G	C	G	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?
103	Bixaceae	A	C	C	A	A	A	C	C	G	G	G	A	A	?	T	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	?	A	T	A	C	C
104	Cochlospermaceae	A	A	C	A	A	A	?	?	G	G	A	A	A	A	G	C	A	A	A	A	A	?	?	?	A	A	A	A	A	C	A	A	A	A	A	A	T	A	C	C
105	Cistaceae	A	C	C	A	A	A	C	C	C	G	G	G	A	A	C	G/T	A/C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	T	A	C	C
106	Malvales s. str.	A	C	C	A	A	C	C	C	C	G	G	A	A	A	C	G	G	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?	T	A	A	C
107	Strasburgeriaceae	A	C	?	A	A	A	?	?	G	G	G	C	A	C	A	A	A	?	A	?	A	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	A	A	C	?
108	Podostemaceae	A	A	A	A	A	A	C	A/C	G	C	A	A	A	A	C	A	A	A	G	?	?	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A	A	A	A	A	?
109	Brunlaceae	A	A	A	A	A	A	?	?	?	G	G	A	A	A	A	G	G	C	A	A	?	?	?	?	?	C	A	?	?	A	?	?	?	?	?	?	?	?	?	?	?
110	Balanophoraceae	A	A	A	A	A	A	A	C	A	G	C	A	C	A	C	A	A	?	A	?	A	C	A	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Appendix 1. Continued.

diff.mat6	12	1 0	1 1	2 1	3 1	4 1	5 1	6 1	7 1	8 1	9 1	7 0	1 7	1 7	2 1	7 3	1 7	4 1	7 5	1 7	6 1	7 7	1 7	8 1	7 9	1 8	0 1	8 1	1 8	2 1	8 3	1 8	4 1	8 5	1 8	6 1	8 7	1 8	8 1	8 9	1 9	0 1	9 1	5 1	9 2	1 9	3 1	9 4	1 9	5 1	9 6	1 9	7 1	9 8	1 9	9 2	0 0
		endc	endc	endc	emb	emb	susc	grow	disp	anor	phlo	wood	inter	corti	scle	wood	fiber	fiber	tracl	libri	type	hom	rays	ston	vasi	vess	end	vess	vess	vess	deni	last	last	last	stip	glan	last	stom	spad	muc	palm	crass	leaf
66	Crossosomataceae	A	A	C	A	A	A	A	A	A	A	A	A	A	C	A	C	A	C	A	C	G	A	A	A	A	T	T	?	A	A	A	C	A	A	C	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A
67	Connaraceae	A	A	C	A	A	A	A/C	A	A	A	A	A	A	A	C	A	A	A	A	C	T	A	C	A	A	T	T	?	G	A	A	?	A	A	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A
68	Oxalidaceae	A	A	C	A	A	A	C	A	A	?	A	A	A	C	C	A	A	C	A	C	T	A	C	A	A	T	T	?	G	C	A	C	A	C	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
69	Stachyuraceae	A	A	C	?	A	A	A	A	A	A	A	A	A	A	C	?	?	C	A	?	?	?	A	A	A	?	C	?	?	?	A	C	A	C	A	A	G	A	?	A	A	C	C	A	C	A	A	A	A	A	A	A	A
60	Geissolomataceae	?	A	G	A	A	A	A	A	A	A	A	A	A	A	C	A	?	A	A	A	A	A	A	?	?	?	?	?	?	A	?	?	C	C	A	A	A	G	?	C	A	A	A	G	?	C	A	A	A	A	A	A	A
61	Geraniaceae	A	A	C	A	A	A	A	A	?	A	A	A	C	A	A	A	A	C	?	?	?	A	A	C	G	A	?	C	A	C	A	C	A	A	G	A	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A
62	Melianthaceae	A/C	A	C	A	A	A	A	A	A	A	A	A	A	C	G	A	A	A	A	G	A	A	C	A	A	C	G	A	?	C	A	C	C	A	A	A	G	C	G	A	A	A	C	C	C	A	A	A	A	A	A	C
63	Fabaceae	?	A	C	A	A	A	A	A	C	C	A	A	A	C	A	A	C	A	C	A	C	A	A	C	C	A	T	C	G	A	C	C	A	?	A	C	A	A	G	A	C	A	?	A	C	A/C	A	A	A	A	A	A
64	Surianaceae	?	C	C	C	A	A	A	A	?	A	A	A	C	A	C	A	A	A	?	?	?	?	A	?	T	C	C	C	A	?	A	C	A	A	G	A	C	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A
65	Polygalaceae	A	A	C	A	A	C	A	A	A	A	C	A	A	A	C	A	C	A	A	A	A	A	T	G	C	C	A	A	A	A	G	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
66	Rhizophoraceae	A	A	C	A	A	A	A	A	?	?	A	?	C	A	C	A	C	A	C	A	A	A	A	C	C	A	C	C	A	C	C	A	C	C	A	A	A/G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
67	Zygophyllaceae	A	A	C	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	C	A	A	T	T	C	G	A	A	A	C	C	A	C	A	A	C	A	C	C	?	A	A	?	A	A	A	A	A	A	C
68	Vochysiaceae	?	?	C	A	A	A	A	A	A	A	A	C	A	C	C	A	A	A	C	C	A	A	A	C	T	T	C	G	A	A	A	C	C	A	C	A	A	G	A	C	C	A	?	A	A	A	A	C	A	A	A	C
69	Myrtales	?	A	G	A	C	C	A	A	C	A	C	A	C	C	C	C	A	C	C	A	A	A	C	A	C	C	A	A	C	C	A	C	C	A	C	A	A	A	G	A	C	C	?	A	A	A	A	C	C	C	C	C
70	Rutales	A	A	C	A	A	A	A	A	A	A	C	C	A	C	C	A	A	A	A	C	A	A	A	C	A	C	G	A	A	G	C	C	C	A	A	A	C	G	A	C	A	C	A									
71	Sapindales	?	A	G	A	A	A/C	A	A	C	A	A	A	A	C	A	A	A	A	A	C	A	A	C	A	C	G	A	A	A	A	C	A	C	A	C	G	A	C	C	C	C											
72	Celastrales	A	A	C	A	A	C	A	A	A	A	A	A	C	A	A	C	A	C	A	A	A	A	A	A	T	C	A	A	A	A	G	A	C	A	A	G	C	A	A/C	A	C											
73	Irvingiaceae	?	?	G	A	A	A	A	A	?	A	A	A	?	G	C	A	A	C	G	A	A	A	A	T	T	?	?	C	A	?	A	C	A	A	A	A	?	A	A	A											
74	Violaceae	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	C	A	?	A	A	A	A	A	C	C	A	A	A	A	A	C	A	C	A	A	A/G	A	C	A/C	A	A											
75	Flacourtiaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	A	G	C	A	A	A	A	C	A	C	A	C	A	C	C	A/G	C	C	C	A	A									
76	Kiggelariaceae	A	A	C	A	A	A	A	A	A	A	C	A	A	C	A	A	C	A	A	A	A	A	A	A	G	C	A	A	A	A	C	A	C	A	A	A/G	C	C	A	A													
77	Salicaceae	A	A	G	A	A	A	A	A	A	C	A	A	A	C	A	A	A	C	T	A	C	A	A	T	T	C	C	C	A	C	A	C	A	A	A	A	A	C	C	A	C											
78	Elaeocarpaceae	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	C	A	G	G	A	G	A	A	C	A	C	A	A	C	A	A	C	A	C											
79	Moringaceae	?	A	G	A	A	A	A	A	A	A	A	A	C	G	A	C	A	A	T	C	A	C	A	T	T	?	G	C	A	?	A	C	?	C	G	A	C	A	A	C											
80	Caricaceae	A	A	C	A	A	A	A	A	C	A	A	A	C	G	?	?	A	A	?	?	A	A	?	?	T	G	G	A	A	C/G	A	C	?	A	G	?	A	C	C	C											
81	Passiflorales	A	A	C	A	A	A/C	A	A	A	A	C	C	A	A	A	A	A	A	T	A	A	A	A	?	T	G	A	G	C	A	A	C	A	C	A	C	G	A	C	C	C											
82	Euphorbiales	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	T	A	A	A	A	A	A	C	A	A	A	A	C	A	C	C	A	A	C	A	A	A/C	C											
83	Capparales	?	A	G	A	A	A	A	A	A	C	C	C	A	A	A	A	C	T	C	A	C	C	C	T	A	G	C	A	C	A	C	A	A	G	A	C	A	?	C													
84	Tropaeolaceae	?	A	T	A	A	C	A	A	A	A	A	A	?	?	?	?	?	?	A	?	?	?	?	?	?	?	C	A	C	A	A	G	A	C	C	?	A															
85	Salvadoraceae	?	A	T	A	A	A	A	?	?	A	C	A	C	A	A	A	A	C	G	A	A	C	A	T	T	?	?	C	A	A	C	C	A	A	A	A	A	C	?	A													
86	Caryocaraceae	A	A	G	C	A	A	A	A	A	A	A	C	G	C	A	A	A	C	C	A	A	A	A	T	C	C	C	A	G	A	C	A	C	G	A	A	A	A	C															
87	Ochnaceae	A	A	C	A	A	A	A	A	A	C	A	A	C	C	A	C	A	A	A	A	A	A	A	A	T	G	A	A	A	A	C	A	C	A	A	A	A	A	?	A	C													
88	Medusagynaceae	A	?	G	A	A	A	A	A	A	C	?	A	C	C	C	C	A	A	C	G	A	A	A	A	?	G	T	A	C	A	A	C	C	A	A	A	G	A	?	A	C													
89	Malpighiaceae	?	?	G	A	A	C	A	A	A	A	A	A	A	C	G	C	A	A	C	A	A	A	A	A	A	C	T	T	?	G	A	A	C	A	C	A	A	A	A	C	A	A	?										
90	Linales s.str.	A	A	C	A	A	C	A	A	A	A	A	A	A	G	C	A	C	A	A	A	A	A	A	A	C	C	A	G	A	A	C	A	C	A	A	A	A	A	C	A	A	A											
91	Clusiaceae	?	A	T	A	A	A	A	A	A	A	A	A	A	C	C	C	A	C	A	A	A	A	A	A	C	G	C	G	A	A	A	C	A	A	A	A	A	A	A	A	A	A											
92	Bonnetiaceae	?	A	G	A	A	A	A	A	A	A	A	A	C	C	C	A	C	A	C	A	A	A	A	A	C	T	C	C	A	A	A	C	A	A	A	A	A	?	A	A	A	A											
93	Elatinaceae	?	A	G	C	A	A	A	A	A	A	A	?	?	?	?	?	C	A	?	?	?	?	?	?	C	?	?	?	?	?	C	C	A	A	A	A	A	A	A	C	C											
94	Quiinaceae	?	A	T	A	A	C	A	A	A	A	A	A	A	C	A	C	A	C	A	A	A	A	A	A	A	T	?	G	A	A	C	A	C	A	A	A	A	A	A	A	A											
95	Chrysobalanaceae	?	A	T	A	A	A	A	A	A	A	A	A	A	G	A	A	C	C	G	A	A	A	A	A	T	T	?	G	A	A	C	A	C	A	A	A	A	A	A	A	A											
96	Dichapetalaceae	?	A	T	A	A	C	A	A	A	A	A	A	A	C	G	C	A	A	A	A	A	A	A	A	?	C	G	A	G	C	A	?	A	C	A	A	A	A	C	A	A											
97	Trigoniaceae	A	A	C	A	A	C	A	A	A	A	A	A	?	C	C	A	C	A	C	A	A	A	A	?	T	G	A	G	A	A	?	A	C	A	A	A	A	C	A	A											
98	Erythroxylaceae	C	A	C	A	A	A	A	A	C	A	C	G	C	A	A	A	A	A	A	A	A	?	T	G	?	G	C	A	C	A	A	C	A	A	A	A	C	A	A	?											
99	Sphaerosepalaceae	A	?	C	A	A	A	A	A	A	C	C	?	?	?	?	?	?	C	A	?	?	?	?	A	?	T	?	?	?	?	?	A	C	A	A	G	A	?	A	A	A											
100	Thymelaeaceae	?	A	C	A	A	A	A	A	A	C	C	A	C	A	A	A	C	A	A	A	A	A	C	C	T	T	G	A	C	A	C	A	C	A	C	A	A	A	G	A	C	A	A										
101	Dipterocarpaceae	?	A	C	C	A	A	A	A	A	C	C	A	C	?	G	C	A	A	?	A	G	A	A	A	C	C	T	T	G	A	C	A	C	A	C	A	A	A	G	A	C	A	A										
102	Sarcolaenaceae	C	?	C	A	A	A	A	A	A	C	C	A	?	?	C	?	C	A	?	?	?	?	?	A	?	T	?	?	?	?	?	C	A	C	A	A	G	A	?	A	A	A											
103	Bixaceae	C	A	C	C	A	A	A	A	A	C	C	A	?	?	A	?	A	A	A	G	A	A	C	C	A	T	T	C	?	A	A	C	A	C	A	A	G	A	?	C	A	A										
104	Cochlospermaceae	A	A	C	C	A	A	A	A	A	C	C	A	A	C	G	A	A	A	A	G	A	A	C	A	T	T	C	G	C	A	C	A	C	A	C	A	A	G	?	C	C	C	C										
105	Cistaceae	C	A	C	C	A	A	A	A	A	C	C	A	A	?	?	?	?	A	?	G	A	A	?	C	T	T	C	G	C	A	C	A	C	A	A	G	A	C	C	C	C											
106	Malvales s. str.	A	A	C	C	A	A	A	A	A	C	C	A	?	?	G	?	?	A	C	G	A	A	C	A	?	?	?	?	?	A	C	A	C	A	A	G	A	C	C	C	?											
107	Strasburgeriaceae	A	?	?	A	A	A	A	A	A	A	A	A	?	C	A	?	C	?	A	A	A	A	A	?	C	C	A	A	A	A	A	C	A	C	A	A	G	?	?	A	A	C											
108	Podostemaceae	?	?	?	A	C	?	A	A	A	A	A	A	A	?	A	A	?	A	?	?	?	A	?	?	?	?	?	?	?	?	A	?	A	A	?	A	A	A	A	A	?											
109	Brunia ceae	?	?	C	A	A	A	A	A	?	C	A	?	C	A	A	C	A	A	A	A	A	A	A	C	C	A	?	A	A	?	A	C	A	A	?	A	A	A	A	A	A											
110	Balanophoraceae	?	?	?	A	A	A	A	A	A	?	A	?	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	?	A	A	A	A	A											


dill.mat5 13
2 0 1 2 0 2 2 0 3 2 0 4 2 0 5 2 0 6 2 0 7 2 0 8 2 0 9 2 1 0 2 1 1 2 1 2 2 1 3 2 1 4 2 1 5 2 1 6 2 1 7 2 1 8 2 1 9 2 2 0 2 2 1 2 2 2 2 2 3 2 2 4 2 2 5 2 2 6 2 2 7 2 2 8 2 2 9 2 3 0 2 3 1 2 3 2 2 3 3 2 3 4 2 3 5 2 3 6 2 3 7 2 3 8 2 3 9 2 4 0
ealic chlo kran leaf vein folia elon corl brac K C peta num high trim sepa peta peta scal peni varu trim isom cent cani cani poly anth inve expa corr valv nect gync carp carp carp carp over carp deg stipl stigr
5 6 Crossosomataceae A A A ? A A A ? A C A T A A A G A A A A A A C ? A C A A A A A C T G A A A A C A
5 7 Connaraceae A A A C A A A ? A C A T A A A G A A A G A C A A A C A A A C C A/T A/G A C A A C A
5 8 Oxalidaceae A A A C C C A A A C A T A A A G A A A G A C A A A C A A ? A C C T G A ? A A A A
5 9 Stachyuraceae A A A A A A A A A C A G A A A G A A A C A C A A A C A A ? A A C T C A C T C A A
6 0 Geissolomataceae A A ? A A A A ? A A A G A A A A A A A G A C A A A C A A C A A C T C A C T C A A
6 1 Geraniaceae A A A A A A A A A C A T A A A G A A A G A C A A A C A A A C A A C T G A A G A A A
6 2 Melianthaceae A A A A A A A ? A C A T A A A G A A A G A C A A A C A A A C A A C T C A G T C A A
6 3 Fabaceae A A C C A C A A A C A T A A A G A A A G A C A A A C A A A C A A C A G A A A A C A A
6 4 Surianaceae A A ? A A A A ? A C A T A A A G A A A G A C A A A C A A A A A ? C T G A G A A C A
6 5 Polygalaceae A A A C C C A A A C A T A A A G A A A G A C A A A C A A A A A C C C A A G T A A A
6 6 Rhizophoraceae A A A C C C A A A C G C C A A T A A A G A C A A A C A A C A C C T G A C T C A A
6 7 Zygophyllaceae A A A C C A A A A C A T A A A G A A A G A C A A A A A A C A C C T G A A T A A A
6 8 Vochysiaceae A A A C C C A ? A C A T A A A C G A A A T A C A A A C A A A C A A A C G A A G T C A A
6 9 Myrtales A A A A C C C A A A C A T A A A G A A A G A C A A A C A A A C A A A C A A/C C T G A A G A A A
7 0 Rutales A A A A C C C A A A C A T A A A G A A A C/G A C A A A A C A A C A C C T G A A C C A A
7 1 Sapindales A A A C C A A A A C A C C A A A G A A A G A C A A A A A A C A C C/G G/T A/G A A G A A A
7 2 Celastrales A A A A C C C A A A C A T A A A G A A A C/G A C A A A A A A C A C C T G A A G A A A
7 3 Irvingiaceae A A A ? C A C A ? A C A T A A A C G A A A G A C A A A C A A C A C C T G A C T C A A
7 4 Violaceae A A A A A A A A A A C A T A A A G A A A C A C A A A A A A G A A C G/T A/G A A T A A A
7 5 Flacourtiaceae C A A A C A A A A A A A C C A A A A A A A A/C A C A C A A A A A G A C A G A A A G A A A
7 6 Kiggelariaceae A A A C A A A A A A A C G A A A A C A A/C A C ? ? A A A A A A A G A A A G A A A
7 7 Salicaceae C A A A A A A A ? A ? ? ? ? A A A A A A A C A C A A A A A C A C/G A A A T A A A
7 8 Elaeocarpaceae A A A A A A A A A C A C G A A A G A A A A A A A C A A A A C A C ? T T C A G A A A
7 9 Moringaceae A A A A A A A A A C A T A A A G A A A G A C A A A C A A A A C C G A A C T C A A
8 0 Cancaceae A A A A A A A ? A C C T A A C G C A A G A C A A A C A A C A C C T G A A G A A A
8 1 Passiflorales A A A C C C A A A C A T A A A G A A A G A C A A A C A A C A A C A ? C G/T A/G A A G A A A
8 2 Euphorbiales A A C C C C A A A C A T A A A G A A A A/C A C ? C A A A C A A C C G A A A G A A A
8 3 Capparales A A A C C C A A A C A/C C/T A/C A A C/G A A A A/C A A/C A C C C A A C A C C T T C A C A A A
8 4 Tropeeolaceae A A A A A A A A A C A T A A A G A A A G A C A A A C A A A A A C G A A G T A A A
8 5 Salvadoraceae A A A A A C A A A C A T A A C G A A A C A C A A A C A A A A A C C C A A A T C A A
8 6 Caryocaraceae A A ? C C A A ? A C A T A A C G A A A A A A C ? A C A A A A A A A/C T G A G G A A A
8 7 Ochnaceae A A A C A A A A A C C C C C A A T A A A A A/C/C A A/C C ? A A A A C A A C C G/T A/G A A C A A A
8 8 Meduasgynaceae A A A A A A A ? A C C A T A A A G A A A A A A ? ? A C A A A A A ? A T T T A G A A A
8 9 Malpighiaceae A A A A A A A A A C A T A A A G A A A G A C A A A C A A C A A A G G A A A G A A A
9 0 Linales s.str A A A C A A A A A C C T A A A G A A A G A C A A A C A A C C T G A C G A A A
9 1 Clusiaceae A A A C A C A A A C A T A A A G A A A A A A A C A A A A C A A C C T T G A G A A A
9 2 Bonnetiaceae A A A ? ? ? A A A C C T A A A G A A A A A A ? ? A C A A ? A A A C T G A C G A A A
9 3 Elatinaceae A A A A A A A A A C A T A A A G A A A G A C A A A C A A A A A C T G A A G A A A
9 4 Quinaceae A A ? C A A A ? A C C T A A A G A A A G A C A A A C A A A A A C T G A A G A A A
9 5 Chrysobalanaceae A A A C A A A ? A C A T A A A G A A A A/G A A/C ? ? A C A A A A A C C/G A A A G A A A
9 6 Dichapetalaceae A A A C A A A ? A C A T A A A G A C A C A C A A A C A A A A C C G A A C G A A A
9 7 Trigoniaceae A A A C A A A ? A C C T A A A G A A A A A A ? ? A C A A A A A G G A A C T C A A
9 8 Erythroxylaceae A A A C A A A A A C A T A A C G A C A G A C A A A C A A A A A C G A A A G A A A
9 9 Spherosepalaceae A A A ? A A A ? A C C T A A A G A A A A/G A A/C ? ? A C A A A A A C C G A A G T C A A
1 0 0 Thymelaeaceae A A A ? A A A A A C A T A A A G A A A C G A C A A A C A A A A A C C C T G A G T C A A
1 0 1 Dipterocarpaceae A A A A A A A ? A C C T A A A G A A A A/G A A/C A C A A A C A A C G/T A/G A A G A A A
1 0 2 Sarcolaenaceae A A ? C A A A ? A C C T A A A G A A A A/G A A/C ? ? A C A A A A C C G A A ? T C A A
1 0 3 Bixaceae A A A A A A A A A C A T A A A G A A A A A A A C A C A A A A ? C C A A G T C A A
1 0 4 Cochlospermaceae A A A A A A A A A C C T A A A G A A A A A A A C A C A A A A A C T G A G T C A A
1 0 5 Cistaceae A A A A A A A A A C C T A A A G A A A A A A A C A C A A A A A C T G A G T A A A
1 0 6 Malvales s. str. A A A A A A A A A C C A T A A A G A A A A A A A C A C A A A A A C T T C G T C A A
1 0 7 Strasburgeriaceae A A ? ? ? ? A ? A C C C G A A A G A A A A G A C A A A C A A C T G A C T C A A
1 0 8 Podostemaceae A A A A A A A ? A A A T A A A A A A A A A A C A C A A A C A C/G A A A G A A A
1 0 9 Bruniaceae A A A C A A A ? A C A T A A A/C G A A A C A C A A A C A C C G A A G A A A
1 1 0 Balanophoraceae A A A A ? ? A ? A A G C C A A C A A A A A A A ? ? ? A A A A A A A C/G A A A G A C A

Appendix 1. Continued.

diff.mat5	14	2 4 1	2 4 2	2 4 3	3	2 4 4	2 4 5	2 4 6	2 4 7	2 4 8	2 4 9	2 5 0	2 5 1	2 5 2
		plac	diffu	stigr	ovar	ovul	ovul	micr	obtu	seec	fruit	type	cent	
5 6	Crossosomataceae	A	A	C	A	T	C	A	A	T	A	A	A	
5 7	Connaraceae	A	A	A	A	G	A/C	?	A	C	A	A	A	
5 8	Oxalidaceae	G	A	A	A	T	C	?	A	T	A/C	C	C	
5 9	Stachyuraceae	T	A	A	A	T	C	A	C	T	C	T	A	
6 0	Geissolomataceae	G	A	A	A	G	C	A	A	C	A	C	A	
6 1	Geraniaceae	G	A	C	A	T	C	A	C	T	A	C	C	
6 2	Meliianthaceae	G	A	A	A	T	C	A	C	A	C	A	C/G	A
6 3	Fabaceae	A	A	C	A	T	C	A	C	T	A	A	A	
6 4	Surianaceae	A	A	A	A	G	C	G	?	?	C	T	A	
6 5	Polygalaceae	G	A	A	A	T	C	A	A	C	A	C	A	
6 6	Rhizophoraceae	G	A	A	A	T	C	C	A	C	A	C	A	
6 7	Zygophyllaceae	G	A	A	A	T	C	A/C	C	T	A	C	A	
6 8	Vochysiaceae	G	A	A	A	T	C	A	A	T	A	C	A	
6 9	Myrtales	G/T	A	A	C	T	C	A	C	T	A	C	A	
7 0	Rutales	A	A	C	A	T	C	C	C	T	A	C	A	
7 1	Sapindales	G	A	A	A	G	C	A	C	G	A	C	A	
7 2	Celastrales	G	A	A	A	T	C	A	A	T	A	C	C	
7 3	Irvingiaceae	G	A	A	A	C	C	A	C	C	C	T	A	
7 4	Violaceae	T	A	A	A	T	C	C	A	T	A	C	A	
7 5	Flacourtiaceae	T	A	A	A	T	A/C	A	A	T	A	C	A	
7 6	Kiggelariaceae	T	A	A	A	T	C	A	A	T	A	C	A	
7 7	Salicaceae	T	A	C	A	T	C	A	A	T	A	C	A	
7 8	Elaeocarpaceae	G	A	A	A	T	C	A	A	T	A	C	A	
7 9	Moringaceae	T	A	A	A	T	C	A	A	T	A	C	A	
8 0	Caricaceae	T	G	A	A	T	C	A	A	T	C	T	A	
8 1	Passiflorales	T	G	A	A	T	C	A	A	T	A	C	A	
8 2	Euphorbiales	G	A	C	A	G	A/C	A/C	C	G	A	C	C	
8 3	Capparales	T	A	A	A	T	C	A	A	T	A	C	A	
8 4	Tropeolaceae	G	A	A	A	C	C	C	A	C	C	T	A	
8 5	Salvadoraceae	G	A	A	A	G	C	C	A	G	C	T	A	
8 6	Caryocaraceae	G	A	A	A	C	C	A	A	A	C	T	?	
8 7	Ochnaceae	G/T	A	A	A	T	C	A	A	T	A	G	C	
8 8	Medusagynaceae	G	A	A	A	G	C	A	?	C	A	G	C	
8 9	Malpighiaceae	G	A	A	A	C	C	A/C	A	C	A	G	A	
9 0	Linales s.str.	G	A	A	A	G	C	C	C	G	A	G	A	
9 1	Clusiaceae	G/T	G	A	A	T	C	A	A	T	A	G	A	
9 2	Bonnetiaceae	G	G	A	A	T	C	A	A	T	A	G	C	
9 3	Elatinaceae	G	A	A	A	T	C	A	A	T	A	G	C	
9 4	Quiinaceae	G	A	A	A	G	C	?	?	T	A	C	A	
9 5	Chrysobelanaceae	?	?	A	A	G	C	A	A	C	C	T	A	
9 6	Dichapetalaceae	G	A	A	A	G	C	C	C	A	C	T	A	
9 7	Trigoniaceae	T	A	A	A	T	C	A	A	T	A	G	C	
9 8	Erythroxylaceae	G	A	A	A	G	C	C	A	A	C	T	A	
9 9	Sphaerosepalaceae	A	A	A	A	T	C	?	?	T	A	C	C	
1 0 0	Thymelaeaceae	G	A	A	A	C	C	C	C	C	A	C	A	
1 0 1	Dipterocarpaceae	G/T	A	A	A	T	C	C	A	A	C	T	A	
1 0 2	Sarcolaenaceae	G	A	A	A	T	C	?	?	T	A	C	A	
1 0 3	Bixaceae	T	G	A	A	T	C	A	A	T	A	C	A	
1 0 4	Cochlospermaceae	T	A	A	A	T	C	A	A	T	A	C	A	
1 0 5	Cistaceae	T	A	A	A	T	A/C	A	A	T	A	C	A	
1 0 6	Malvales s. str.	G	A	A	A	T	A	A	A	T	A	C	A	
1 0 7	Strasburgeriaceae	G	A	A	A	C	C	?	C	A	C	T	A	
1 0 8	Podostemaceae	G	G	A	A	T	C	A	A	T	A	G	A	
1 0 9	Bruniaceae	G	A	A	C	T	C	G	A	G	A	A	A	
1 1 0	Balanophoraceae	G	A	A	A	C	A	T	A	A	C	T	A	

Appendix 1. Continued.

dill.mat5	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
		sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	sero	Al a	amic	dhui	proti	trigli	taxi	proa	hete	card	valin	linei	tota	linui	neol	tyroi	prun	sam	zieri	holo	gluc	dihy	acel	eleo	myr
111	Santalales	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	A	C	A	A
112	Aextoxicaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
113	Paracryphiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
114	Pentaphylacaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
115	Oncothecaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
116	Sphenostemonoaceae-Aqu	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
117	Icacinaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A
118	Balsaminaceae	?	?	?	?	?	?	?	A	A	A	?	A	A	A	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?
119	Pouguieriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A
120	Polemoniaceae	?	?	?	?	A	A	A	?	?	C	?	?	?	C	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?
121	Loasaceae	?	?	?	?	A	A	A	?	?	C	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
122	Cornales	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A
123	Hydrangeaceae	?	A	A	A	?	?	?	?	?	?	?	A	C	?	?	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	A	A	A	A	A	A	A
124	Diapensiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
125	Scytopetalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
126	Lecythidaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?
127	Sapotaceae	?	?	?	?	?	?	?	?	?	?	?	C	C	C	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	A	A	?
128	Ebenaceae	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A
129	Styracaceae	?	?	?	?	A	A	A	?	?	?	A	?	C	C	?	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?
130	Primulales	?	?	?	?	A	A	C	A	A	A	C	C	C	C	C	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?
131	Clethraceae	?	?	?	?	?	?	?	?	?	?	?	C	C	C	C	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
132	Actinidiaceae	?	?	?	?	A	A	A	?	?	?	C	C	C	C	C	?	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	A	?
133	Sarracheniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	?	A
134	Ericales	?	?	?	A	A	A	C	?	?	?	C	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
135	Marcgraviaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
136	Cyrillaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	
137	Theaceae	?	?	?	?	A	A	C	?	?	?	A	C	C	C	C	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
138	Pittosporaceae	?	?	?	?	A	?	?	A	A	A	?	?	?	?	?	?	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	A
139	Araliales	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	C	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
140	Escalloniaceae	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?
141	Dipsacales	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	C	C	A	A	A	C	A
142	Eucommiales	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	A	?
143	Gentianales	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	C	A	A	A	A
144	Scrophulariales	?	?	?	A	?	?	?	A	A	A	?	?	?	?	?	A	C	C	A	A	A	A	A	A	A	A	C	A	A	A	A	C	C	A	A	A	A	A	C	C
145	Solanales	?	?	?	?	A	A	A	A	A	A	A	C	?	?	?	?	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A
146	Symplocaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?
147	Menyanthaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
148	Campanulales	?	?	?	?	A	A	A	A	A	A	C	A	A	A	?	?	A	C	A	A	C	A	C	A	A	A	C	C	A	A	C	C	C	C	A	A	A	A	A
149	Akaniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?
150	Bretschneideraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?
151	Corynocarpaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
152	Huaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?
153	Krameriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
154	Lacistemaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
155	Lertneriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
156	Pellicieraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
157	Peridiscaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
158	Plagiopteraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
159	Scyphostegiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
160	Tetrameristaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
161	Tremandraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Appendix 1. Continued.

dill.mat5	16	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
		asar	sesc	pern	myo	prni	quel	dact	cani	cycl	aimn	aust	kadc	eucc	syri	pino	dilly	gaib	licar	vera	prod	ellac	metl	stac	cass	tellin	tellir	peck	gera	chlo	gall	epig	flav	afze	davi	bifla	Ourr	euxi	norz	mac	benz
111	Santalales	A	A	A	C	C	C	A	A	A	A	A	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	C	A	?	A	A	A	A	A	A	A
112	Aextoxicaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
113	Paracryphiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
114	Pentaphylacaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
115	Oncothecaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	?	?	?	?	?	?	?	?
116	Sphenostemonaceae-Aqu	?	A	A	?	?	?	?	?	A	C	A	A	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
117	Icacinaceae	A	A	C	A	A	?	A	C	A	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	C
118	Balanitaceae	?	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	?
119	Fouquieriaceae	A	A	A	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	A	C	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	?	A	A
120	Polemoniaceae	?	?	?	?	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A
121	Loasaceae	?	?	?	?	?	A	C	A	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
122	Cornales	A	A	A	C	A	A	?	A	A	A	A	A	A	A	A	A	A	A	A	C	C	?	A	A	A	C	A	A	C	A	A	C	A	?	A	A	A	A	C
123	Hydrangeaceae	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	A	A	A	C	A	A	C	A	A	C	A	?	A	A	A	A	C
124	Diapensiaceae	A	?	?	?	?	?	C	A	?	?	?	?	?	?	?	?	?	?	?	?	C	A	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?
125	Scytopetalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
126	Lecythidaceae	?	A	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	C	C	C	?	?	?	?	?	?	?	C	?	?	?	?	?	A	?	?	A
127	Sapotaceae	?	A	A	C	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
128	Ebenaceae	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A	A	A	C	C	C	?	?	?	?	?	?	C	?	?	?	?	?	A	?	?	A
129	Styracaceae	?	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A
130	Primulales	?	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	C	C	A	?	?	?	?	?	?	?	A	?	?	?	?	?	A	?	?	A
131	Clethraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	C	?	?	?	?	?	?	?	?	?	?
132	Actinidiaceae	?	A	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A
133	Sarraceniaceae	A	?	?	?	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	?	?
134	Ericales	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	A	A	A
135	Marcgraviaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
136	Cyrillaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
137	Theaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	C	C	C	C	A	A	A	C	A	A	A	A
138	Pittosporaceae	A	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A
139	Araliales	C	C	C	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	C	A	?	?	?	?	?	?	?	?	C	A	?	C	A	?	?	?	A	?	?	A
140	Escalloniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
141	Dipsacales	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	C	C	A	A	A	A
142	Eucommiales	?	?	A	A	A	A	A	A	A	A	?	?	A	C	C	C	A	A	A	A	A	C	A	?	?	?	?	?	?	?	A	?	?	?	?	A	?	?	A
143	Gentianales	A	C	C	C	C	C	A	A	A	A	A	A	C	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	A	A	C	C
144	Scrophulariales	C	C	C	C	A	A	A	A	A	C	A	A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	A	C	A	A	A	A	A	A
145	Solanales	A	A	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A
146	Symplocaceae	?	?	?	A	A	A	A	A	A	?	?	A	A	A	C	A	A	A	A	C	C	A	?	?	?	?	?	?	C	?	?	?	C	?	?	A	A	A	C
147	Menyanthaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?
148	Campanulales	C	C	C	C	C	C	A	C	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	C	C	A	C	A	A	A
149	Akaniaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?
150	Bretschneideraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
151	Corynocarpaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A
152	Huaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	A	?	A	A	?	?	?	?	?	?	?	?	?
153	Krameriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
154	Lacistemaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
155	Leitneriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
156	Pellicieraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
157	Peridiscaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
158	Plagiopteraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
159	Scyphostegiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
160	Tetrameristaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
161	Tremandraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Appendix 1. Continued.

dill.mat5	17	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
		roan	anor	iirlox	prot	anci	cam	indo	indo	secc	corn	olea	arjun	dem	cucu	rajpr	arbu	napl	rapa	plum	dros	anth	pher	antiy	actir	nitro	chro	stew	strat	rod	epic	SiO2	oxal	elon	soilt	crys	sphi	myri	oil c	muc	resir
111	Santalales	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	?	?	?	?	?	?	A	A	A	A	C	?	?	?	C	C	A	C	A	A	C	C	C
112	Aextoxicaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	C	A	C	A	A	A	?	A
113	Paracryphiaceae	?	A	A	?	?	A	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A	A	A	A	A	G	C	A	A	A	A	A	?
114	Pentaphylacaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	A	A	G	C	A	A	A	A	C	A
115	Oncothecaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	A	A	A	A	C	G	C	?	A	A	A	?	?
116	Sphenostemonaceae-Aqu	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	?	?	?	?	?	?	C	A	A	A	A	C	A	A	A	C	A	C	G	C	C	A	A	C	C
117	Icacinaceae	A	A	A	A	C	A	C	A	A	A	A	A	A	?	A	?	?	?	?	?	?	?	?	?	A	A	A	C	A	A	A	A	C	A	C	C	A	A	C	A
118	Balsaminaceae	?	?	?	?	?	A	?	A	A	A	?	?	?	A	?	A	C	A	A	A	A	A	A	A	A	?	C	C	?	?	?	A	C	A	C	A	A	A	C	A
119	Fouquieriaceae	A	A	A	A	A	A	C	C	A	A	?	?	C	A	C	A	A	A	A	A	A	A	A	A	A	A	C	C	?	?	?	A	C	A	C	A	A	A	C	C
120	Polemoniaceae	?	?	?	?	?	?	?	?	?	?	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	?	A	A	C	?	?	?	A	C	G	C	A	A	A	C	A
121	Loasaceae	?	?	?	?	?	?	C	C	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	?	?	?	?	A	C	A	C	A	A	A	A	A	A
122	Cornales	A	A	A	A	A	C	C	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	C	C	A	A	C	A
123	Hydrangeaceae	A	A	A	A	A	?	?	C	?	?	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	C	A	A	A	C	A
124	Diapensiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	?	?	?	A	C	A	C	A	A	A	A	A
125	Scytopetalaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	A	A	?	A	A	A	C	A	A	A	A	A
126	Lecythidaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	?	?	?	?	A	A	A	A	A	A	A	C	A	A	A	C	A	C	A	A	A	A	C	C
127	Sapotaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	C	?	?	?	C	C	A	C	C	A	A	A	C
128	Ebenaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	C	A	C	C	A	A	A	A	A	A	A	C	?	?	?	C	A	C	A	C	A	A	A	A
129	Styracaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	?	A	A	?	?	?	?	A	A	A	A	A	A	A	C	?	?	?	C	C	A	C	A	A	A	A	C
130	Primulales	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	C	C	A	?	?	?	C	C	G	C	A	A	A	C
131	Clethraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	C	A	C	A	C	A	A	A	A
132	Actinidiaceae	A	A	A	A	A	?	A	C	A	A	?	?	?	A	?	?	?	?	?	?	?	?	?	?	C	A	A	C	C	C	A	A	A	C	A	C	A	A	A	A
133	Sarraceniaceae	?	?	?	?	?	?	C	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	A	C	C	?	?	?	A	A	A	C	A	C	A	A	A	A
134	Ericales	A	A	A	A	A	A	A	C	A	A	?	A	A	A	A	C	C	A	A	A	A	A	?	A	A	A	C	C	A	C	A	C	A	C	A	C	A	A	A	A
135	Marcgraviaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	A	A	A	A	C	A	A	?	A	A	C	C
136	Cyrillaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	A	C	A	C	A	A	A	A	A
137	Theaceae	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	C	A	C	C	A	C	G	C	A	A	C
138	Pittosporaceae	A	A	A	A	A	A	A	?	A	C	A	A	A	?	?	?	?	?	?	?	?	?	?	?	A	A	C	A	C	A	C	A	C	G	C	A	A	A	A	C
139	Araliales	A	A	A	A	A	A	A	?	A	A	C	A	A	A	?	?	?	?	?	?	C	C	A	A	A	C	?	?	?	A	C	G	C	C	A	A	A	A	C	C
140	Escalloniaceae	A	A	A	A	A	A	C	?	?	?	?	?	A	?	?	?	A	A	A	?	?	?	A	A	A	C	?	?	?	A	C	G	C	C	A	A	A	A	C	C
141	Dipsacales	A	A	A	A	?	?	C	C	C	?	C	A	A	A	A	C	A	A	A	A	A	A	A	C	A	A	C	A	C	A	A	C	A	C	C	A	A	A	A	A
142	Eucommiales	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	?	?	?	C	C	A	C	C	A	A	A
143	Gentianales	A	A	A	A	A	A	C	C	C	?	C	C	C	C	A	C	C	A	A	A	A	C	A	C	C	A	C	C	C	A	A	C	C	C	C	C	A	A	C	C
144	Scrophulariales	A	A	A	A	A	A	A	A	C	A	C	C	A	C	C	A	C	C	A	A	A	C	A	C	C	A	C	C	?	?	?	C	C	G	C	A	C	A	A	C
145	Solanales	A	A	A	A	A	A	?	A	A	C	A	C	A	A	C	C	C	A	A	A	A	C	A	A	C	C	?	?	?	C	C	G	C	C	A	A	A	A	A	A
146	Symplocaceae	A	A	A	A	A	A	C	C	?	C	C	C	A	A	?	?	?	?	?	?	?	?	?	A	A	A	C	?	?	?	A	C	A	C	A	A	A	A	A	A
147	Menyanthaceae	?	?	?	?	?	?	?	C	C	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	A	?	?	A	A	A	A	A	A	A	A	A	A	A	A	A
148	Campanulales	A	A	A	A	A	A	A	C	C	A	A	C	A	A	C	A	A	A	A	C	A	A	C	A	A	C	C	A	A	A	A	C	C	G	C	C	C	A	A	C
149	Akaniaceae	?	?	?	?	?	?	?	?	?	?	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	C	C	A	A	A	A	A
150	Bretschneideraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	A	?	?	?	?	?	C	A	A	A
151	Corynocarpaceae	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	?	?	?	A	C	G	C	A	A	A	A	A	A
152	Huaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	?	?	?	A	A	C	A	C	A	A	A	A	A
153	Krameriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	C	C	?	?	?	?	C	A	A	C	C	A	A	A	A
154	Lacistemaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	C	A	A	A	A	C
155	Leitneriaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	C	?	?	?	A	C	A	A	A	A	A	A	C
156	Pellicieraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	A	C	C	A	A	A	A	A	A
157	Peridiscaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	C	A	C	A	A	A	A	A
158	Plagiopteraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	?	C	A	C	A	A	A	A	A
159	Scyphostegiaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	A	C	A	C	A	A	A	A	A
160	Tetrameristaceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	A	A	A	A	C	A	C	A	A	A	A	A
161	Tremandraceae	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	?	?	?	?	?	A	C	A	C	A	A	A	C	A	C

Appendix 1. Continued.

dlll.mat5	18	1 2 1	1 2 2	1 2 3	1 2 4	1 2 5	1 2 6	1 2 7	1 2 8	1 2 9	1 3 0	1 3 1	1 3 2	1 3 3	1 3 4	1 3 5	1 3 6	1 3 7	1 3 8	1 3 9	1 4 0	1 4 1	1 4 2	1 4 3	1 4 4	1 4 5	1 4 6	1 4 7	1 4 8	1 4 9	1 5 0	1 5 1	1 5 2	1 5 3	1 5 4	1 5 5	1 5 6	1 5 7	1 5 8	1 5 9	1 6 0
		latic	lasc	petiz	denc	nonc	glan	anth	micr	polle	type	pola	trian	tnan	ang	sequ	type	inte	inte	nuce	peri	endc	occi	occu	occu	end	e rll	pacf	earc	rumi	exot	exot	theo	tann	mas	endc	endc	exot	exot	bixo	hypc
111	Santalales	C	C	A	C	A	A	C	C	G	C	A	C	A	C	A	A	A	A	C	A	C	A	C	A	A	A	A	A	A	A	A	A	?	A	A	A	A	A	A
112	Aextoxicaceae	A	?	?	?	A	?	?	?	G	G	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	A	?	?	?	A	?	?	?	?	?	?	?	?
113	Paracryphiaceae	A	A	A	A	A	?	?	G	G	?	?	A	A	A	G	G	C	A	A	?	C	?	?	?	?	A	A	A	A	?	?	?	A	A	A	A	A	?
114	Pentaphylacaceae	A	A	?	?	A	?	?	?	G	G	A	A	A	A	A	A	A	A	G	?	?	?	?	?	?	A	A	?	?	A	?	C	?	?	?	?	?	?	?
115	Oncothecaceae	A	A	?	?	A	?	?	?	G	G	A	A	A	A	A	G	C	C	A	A	?	?	?	?	?	?	A	?	?	?	A	?	?	C	?	A	A	A	A	A
116	Sphenostemonaceae-Aqu	A	A	A	A	A	A	?	?	G	G	A	A	A	A	A	A	C	A	A	A	C	C	A	A	G	A	A	A	A	A	A	C	A	A	A	A	A	C
117	Icacinaceae	C	C	C	A	A	A	C	C	G	G	C	A	C	A	C	C	A	C	A	A	A	A	?	?	?	C	A	A	C	?	A	A	A	?	?	C	A	A	A	A
118	Balsaminaceae	A	A	A	A	A	A	C	C	G	G	C	C	C	A	A	G	G	A	C	C	A	G	A	C	A	A	A	?	?	A	A	A	A	C	A	A	A	A	A	A
119	Fouquieriaceae	A	A	A	A	A	A	C	?	G	G	G	A	A	A	G	G	A	A	G	A	C	A	A	A	?	?	A	A	A	A	C	A	A	A	A	?	A	A	A
120	Polemoniaceae	A	A	A	C	A	A	C	C	G	G	G	A	A	A	T	A	C	A	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	A	A	A
121	Loasaceae	A	A	A	A	A	A	?	?	G	G	C	A	A	A	G	G	C	C	G	A	C	A	A	A	A	A	A	A	A	A	A	A/C	A	?	A	A	A	A	A	C
122	Cornales	C	C	C	A	C	A	C	C	G	G	A	C	A	C	A	A	C	C	A	A	A/C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C
123	Hydrangeaceae	A	C	A	A	A	A	?	?	G	C/G	A	A	A	A	G	G	C	C	C	A	A/C	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A
124	Diapensiaceae	A	A	A	A	A	A	C	C	G	G	A	A	A	C	G	C	C	C	G	A	C	A	A	A	A	A	A	?	?	A	A	C	A	A	?	A	A	A	A	A
125	Scyphopetalaceae	A	A	A	A	A	A	C	C	G	C	C	C	A	C	A	A	A	C	G	A	A	C	?	?	?	G	A	A	A	A	C	A	A	A	A	A	A	A	A
126	Lecythidaceae	A	C	A	A	A	A	C	C	G	C	C	A	A	A	A	A	A	C	G	A	A	?	?	?	G	C	A	A	A	A	A	A	A	C	A	A	A	A	A	A
127	Sapotaceae	A	A	A	A	C	A	C	?	G	G	C	A	A	A	A	A	A	A	C	A	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	?	A	A	A	C
128	Ebenaceae	A	C	C	A	C	C	?	C	G	G	C	A	A	A	A	A	A	C	C	A	C	A	A	A	G	A	C	A	C	A	A	A	A	C	C	A	A	A	A	C
129	Styracaceae	A	C	C	A	A	A	C	C	G	G	C	A	A	A	A	A	A	C	G	A	C	A	A	A	C	A	A	A	A	A	A	?	?	A	A	A	A	A	A	A
130	Primulales	A	A	C	C	A	A	C	C	G	G	C	C	A	A	A	A	G	G	A	C	G	A	A	C	A	A	A	C	A	A	A	C	C	A	A	C	A	C	A	A	A
131	Clethraceae	A	C	A	A	A	A	C	C	G	G	A	A	A	A	C	A	A	C	C	G	A	C	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A
132	Actinidiaceae	A	C	A	C	A	A	C	C	G	G	A	A	A	A	A	A	C	C	G	A	C	A	A	A	A	G	C	A	A	A	A	A	C	C	A	A	A	A	A	A	C
133	Sarraceniaceae	A	A	A	A	A	A	C	C	G	G	A	A	A	A	A	A	A	C	G	A	C	?	?	?	A	A	A	A	A	A	C	A	C	?	A	A	A	A	A	C
134	Ericales	A	C	C	C	A	C	C	C	G	G	A	A	A	C	A	A	C	C	G	A	C	C	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	A	A	?
135	Marcgraviaceae	A	A	A	A	A	A	C	C	G	G	A	A	A	A	A	A	A	A	C	A	C	?	?	?	G	A	A	A	A	A	A	C	C	C	C	A	A	A	A	?
136	Cyrillaceae	A	A	A	A	A	A	C	C	G	G	A	A	A	A	A	A	C	C	G	A	C	?	?	?	?	A	A	A	A	A	A	A	?	?	A	?	A	A	A	A	C
137	Theaceae	A	C	A	A	A	A	C	C	G	G	A	A	A	A	A	G	C	A	A	G	A	A	A	A	A	A	G	C	A	A	A	A	A	C	C	A	A	A	A	C
138	Pittosporaceae	A	A	A	A	C	A	C	C	G	G	A	A	A	A	A	G	A	C	A	G	A	A	A	A	A	A	A	A	A	A	A	A	A	?	A	?	A	A	A	C
139	Araliales	A	C	A	C	C	C	C	C	G	G	A	C	A	A	G	G	C	C	A	G	A	A	A	A	A	A	A	A	C	A	A	A	A	A	?	A	A	A	A	C
140	Escalloniaceae	A	C	C	A	C	C	?	?	G	G	A	A	A	A	C	A	C	?	G	A	C	?	?	?	?	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?
141	Dipsacales	A	C	C	A	A	C	A	C	G	G	C	C	A	C	C	A	C	C	A	A	C	A	C	A	G	A	A	A	C	A	A	C	C	?	A	?	A	A	A	C
142	Eucommiales	C	A	A	A	A	A	C	C	G	G	G	A	C	A	A	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	?	A	?	A	A	A	C
143	Gentianales	C	C	C	C	C	A	C	C	G	G	C	A	C	C	A	A	C	C	G	A	C	C	C	A	A	G	C	C	A	C	C	A	C	C	C	A	A	A	A	C
144	Scrophulariales	C	C	C	C	C	C	C	C	G	G	C	C	C	A	C	G	G	C	C	G	A	C	C	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C
145	Solanales	A	C	C	C	C	C	C	C	G	C	C	A	A	A	C	C	A	C	C	A	A	C	C	A	A	C	A	A	A	A	A	C	A	C	A	A	A	A	A	C
146	Symplocaceae	A	A	A	A	A	A	C	C	G	G	A	C	A	C	C	A	C	C	G	A	C	A	A	A	G	A	A	A	A	A	A	C	C	?	A	?	A	A	A	C
147	Menyanthaceae	A	A	A	A	A	A	C	C	G	G	A	A	C	A	A	T	A	C	C	G	A	C	A	A	C	G	A	A	A	A	A	C	A	A	A	A	A	A	A	C
148	Campanulales	C	C	C	C	C	C	C	C	G	G	A	C	A	C	C	A	C	C	G	A	C	A	A	A/C	G	A	A	A	A	A	A	C	A	A	A	A	A	A	A	C
149	Akaniaceae	A	A	A	A	A	A	C	?	G	C	G	A	A	A	G	G	A	A	A	A	A	?	?	?	C	A	A	A	A	A	A	C	A	A	C	A	A	A	A	C
150	Bretschneideraceae	A	A	A	A	A	A	C	?	G	C	G	A	A	A	G	G	A	A	A	A	A	?	?	?	G	A	A	A	A	A	A	C	A	A	C	A	A	A	A	C
151	Corynocarpiaceae	A	A	C	A	A	A	?	?	G	G	C	A	A	A	A	A	A	A	A	A	A	?	?	?	?	A	A	A	A	A	A	C	A	A	?	A	?	A	A	A	C
152	Huaceae	A	C	C	A	A	A	?	?	G	T	C	A	A	A	G	G	A	A	?	A	?	?	?	?	G	A	A	A	A	A	C	A	A	?	A	A	T	A	A	?
153	Krameriaceae	A	A	A	A	A	?	?	?	G	G	?	A	A	A	T	A	A	A	A	A	A	?	?	?	C	A	A	A	A	A	A	C	A	A	A	A	A	A	A	C
154	Lacistemaceae	A	A	A	A	A	A	?	?	G	G	A	A	A	A	G	C	A	?	A	A	A	?	?	?	?	A	?	C	A	A	A	A	?	?	A	?	A	?	?	?
155	Leitneriaceae	A	A	A	A	A	A	C	?	G	G	C	A	A	A	G	G	A	A	A	C	A	?	?	?	A	A	A	A	A	A	A	A	C	A	G	A	A	A	A	A
156	Pellicieraceae	A	A	A	A	A	A	?	?	G	G	G	A	A	A	A	A	A	A	?	?	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?
157	Pentdiscoceae	A	A	A	A	A	A	?	?	G	G	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
158	Plagiostyleaceae	A	C	A	A	A	A	C	C	G	G	C	A	A	A	G	C	A	C	C	A	?	?	?	?	?	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?
159	Scyphostegiaceae	A	A	A	A	A	A	?	C	G	C	?	?	?	?	?	A	A	A	A	A	?	?	?	A	C	A	A	A	C	A	A	A	A	A	G	A	A	C
160	Tetrameristaceae	A	A	A	A	A	A	?	?	G	G	G	A	A	A	G	G	A	A	?	?	?	?	?	?	A	A	A	A	A	A	C	A	A	?	?	?	?	?	?	C
161	Tremandraceae	A	C	A	A	A	A	?	?	G	G	A	A	A	A	A	A	A	A	A	A	?	?	?	?	A	C	A	A	A	C	A	A	A	?	?	?	A	?	?	C

dill.mat5	19	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	2	0	0
		anoic	anoic	embr	embr	susp	grow	disp	anor	phlo	weak	inter	corti	sclen	woo	fiber	fiber	tracl	librif	type	hom	rays	storo	vesti	vess	and	vess	vess	vess	denc	leaf	leaf	stipu	glan	leaf	ston	epid	muci	palm	cras	leaf
111	Santalales	A	C	A	A	A	A	A	A	A	A	A	A	C	C	C	A	C	A	A	A	A	A	A	C	C	A	G	A	A	C	A	A	A	A	A/G	A	A	A	A	A
112	Aextoxicaceae	?	?	C	A	A	?	A	A	?	A	A	?	?	C	A	A	C	A	A	A	A	A	A	C	C	A	?	C	A	?	?	?	?	A	A	A	A	C	?	?	?	A	A
113	Paracryphiaceae	?	?	C	A	A	?	A	A	?	?	A	A	C	C	A	C	A	A	A	A	A	A	A	C	C	A	A	C	C	A	C	A	A	A	A	G	A	A	A	A	C
114	Pentaphylacaceae	?	?	G	C	A	A	A	A	A	A	A	A	C	C	C	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	A	A	A	C	A	A	A	A	?	A	A	A	A
115	Oncothecaceae	?	?	C	A	A	?	A	A	A	A	A	A	C	C	C	A	C	A	A	A	A	A	A	C	C	A	A	A	A	A	G	A	A	A	A	G	A	?	A	A	A	C
116	Sphenostemonaceae Aqu	A	A	A	A	A	A	A	A	A	A	A	?	C	A	A	C	A	A	A	A	A	A	?	A	C	C	A	A	A	A	A	C	A	A	A	A	G	A	?	A	A	A	C
117	Icacinaceae	A	C	C	A	A	C	A	A	?	A	C	A	C	C	A	A	C	A	A	A	A	A	A	C	C	A	C	A	A	C	A	A	A	A	C	A	A	C	A	A	A	C
118	Balsaminaceae	?	C	T	A	A	A	A	A	A	A	A	A	A	?	?	?	A	?	?	?	?	?	?	?	T	?	?	?	?	A	A	C	A	A	G	A	A	A	A	C
119	Fouquieriaceae	A	C	G	A	A	A	A	A	A	A	A	A	C	G	C	A	A	A	A	A	A	A	A	C	G	A	C	C	A	A	A	A	A	G	A	?	A	A	A	A	C
120	Polemoniaceae	A	A	C	A	A	C	A	A	A	A	A	A	C	?	?	A	C	A	T	A	C	?	A	?	G	A	?	?	?	A	A	A	A	A	G	A	A	A	A	A	C
121	Loasaceae	A	C	C	A	A	C	A	A	?	A	A	A	A	?	A	A	A	A	C	A	A	C	A	C	T	?	?	?	A	?	A	A	A	A	G	A	A	A	A	A	?
122	Cornales	A	A	C	A	A	A	A	A	A	A	A	A	C	G	A	A	A	A	C	A	A	A	A	C	C	A	?	C	A	A	A	A	A	G	A	A	A	A	A	A	C
123	Hydrangeaceae	A	?	C	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	C	A	A	A	A	C/G	C	A	A	A	A	A	?	C	C	C
124	Diapensiaceae	?	A	C	A	A	A	A	A	?	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	G	A	C	?	?	A	A	A	A	A	G	A	A	A	A	A	C
125	Scytopetalaceae	A	A	C	A	A	C	A	A	C	A	A	C	A	G	C	A	A	A	G	A	A	A	A	T	G	?	?	?	?	C	A	A	A	A	G	A	?	A	A	C
126	Lecythidaceae	?	A	C	?	A	A	A	A	C	C	A	C	C	A	C	A	C	A	A	A	A	A	A	C	G	C	G	C	A	G	A	C	A	A	G	A	A	A	A	A
127	Sapotaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	A	C	A	A	A	A	T	G	?	G	C	C	C	A	C	A	A	G	A	A	A	A	A
128	Ebenaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	G	C	A	A	A	A	A	A	A	C	A	C	T	A	A	C	A	A	A	A	A	G	A	A	A	A	A	A
129	Styracaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	G	A	A	A	A	C	A	A	A	A	C	C	A	?	C	A	A	A	A	A	A	G	A	A	A	A	A	C
130	Primulales	A	A	C	A	A	A	A	A	?	A	A	A	C	A	A	A	A	C	A	A	A	C	A	C	G	A	A	C	?	A	A	A	A	A	G	A	C	A	A	A	C
131	Clethraceae	A	C	C	A	A	A	A	A	A	A	A	A	A	G	A	A	C	A	A	A	A	A	A	G	C	A	C	A	A	C	A	A	A	A	A	A	A	A	A	A	C
132	Actinidiaceae	A	A	C	A	A	C	A	A	A	A	A	A	?	C	A	A	C	A	A	A	A	A	A	?	C	C	A	C	A	A	C	A	A	A	A	G	A	A	A	A	A	C
133	Sarracaniaceae	A	A	A	A	A	A	A	A	A	A	A	A	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	A	A	A	A	A	G	A	A	A	A	A	A
134	Ericales	A	C	C	A	A	A	A	A	A	A	A	A	C	C	C	A	A	A	C	C	A	A	A	C	C	A	C	A	A	A	A	A	A	A	G	A	A	A	A	A	A
135	Marcgraviaceae	C	C	G	A	A	C	A	A	A	A	A	A	C	C	A	C	A	C	A	A	A	A	A	G	C	A	G	A	A	A	A	A	A	A	A	A	A	A	A	A	A
136	Cyrillaceae	?	C	C	A	A	A	A	A	A	A	A	A	C	C	A	A	A	A	C	A	A	A	A	C	C	A	G	A	A	?	A	A	A	A	G	A	C	A	A	A	A
137	Theaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	A	C	A	A	A	A	A	A	C	C	A	A	C	A	A	A	A	A	A	C/G	A	A	A	A	A/C	
138	Pittosporaceae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A	C	G	C	A	A	A	A	C	A	A	A	A	A	A	C	A	A	
139	Araliales	A	A	A	A	A	A/C	A	A	A	A	A	C	C	A	A	A	A	C	C	A	A	A	A	C	C	A	A	C	C	G	A	C	A	A	A	A	A	A/C	C	C	
140	Escalloniaceae	?	?	C	A	A	A	A	?	A	A	A	C	C	A	A	C	A	A	A	A	A	A	A	C	C	A	A	A	A	C	A	A	A	A	A	A	A	A	A	C	
141	Dipsacales	A	A	C	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	C	C	A	A	A	A	C	C	C	A	A	G	A	A	A	A	A	C
142	Eucommiales	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A	A	A	A	A	A	A	G	C	A	C	A	A	C	C	A	A	A	G	A	A	C	A	C	
143	Gentianales	A	C	C	A	A	A/C	A	A	A	A	C	A	C	A	A	A	C	A	A	A	A	A	C	C	T	G	?	C	A	C	C	C	C	A	A	A/G	A	C	A	C	
144	Scrophulariales	A	A/C	G	A	A	A/C	A	A	A	A	C	A	C	C	A	A	A	A	C	A	A	C	C	T	T	?	G	A	C	C	C	C	A	A	G	C	A	A/C	A	C	
145	Solanales	A	C	C	A	A	A/C	A	A	A	A	C	A	C	A	A	A	C	A	A	A	A	C	A	T	T	?	G	A	C	C	A	A	A	A	A/G	A	A	C	A	C	
146	Symplocaceae	A	A	C	A	A	A	A	A	A	A	A	A	C	G	A	A	C	A	A	A	A	A	A	C	C	A	?	C	A	A	A	A	A	A	A	A	A	A	A	A	C
147	Menyanthaceae	C	A	C	A	A	A	A	A	A	A	A	C	C	?	?	?	?	?	?	?	A	A	C	?	?	?	A	A	C	A	A	A	A/C	G	A	A	C	A		
148	Campanulales	A	A/C	C	A	A	A	A	A	?	A	A	A	C	C	A	A	C	A	T	C	A	C	A	T	T	C	?	?	A	A	C	A	A	A	A	G	A	A	A	A	C
149	Akaniaceae	?	A	C	A	A	A	A	A	A	A	A	A	C	G	A	C	A	A	A	A	A	A	A	G	G	C	C	C	A	?	A	A	A	C	?	A	A	A	A	C	
150	Bretschneideraceae	?	A	G	A	A	A	A	A	?	?	A	?	?	G	A	A	A	A	A	A	A	A	A	C	G	A	A	C	A	?	A	A	A	C	?	?	?	A	A	A	
151	Connoraceae	?	A	G	A	A	A	A	A	A	A	A	A	C	G	C	A	A	C	G	A	A	C	A	T	T	?	G	C	A	C	A	C	A	A	A	A	A	A	A	A	
152	Huaceae	C	A	C	A	A	A	A	A	C	A	A	C	G	C	A	A	C	G	A	A	A	A	A	T	T	C	G	C	A	C	A	C	A	A	A	A	A	C	A	A	
153	Krameriaceae	?	?	T	A	A	A	A	A	A	A	A	A	C	A	A	A	A	T	A	C	A	A	A	T	T	?	G	A	A	C	A	A	A	A	C	A	A	A	A	A	
154	Lacistemaceae	A	?	C	A	A	A	A	A	?	A	A	A	C	C	C	A	C	A	A	A	A	A	A	G	C	A	G	C	A	C	A	C	A	A	G	A	A	A	A	C	
155	Leitneriaceae	C	A	G	A	A	A	A	C	C	A	A	C	A	A	A	C	T	A	C	A	A	A	C	T	T	?	?	C	C	C	A	A	A	A	G	A	A	A	A	A	
156	Pallideraceae	?	?	T	C	A	A	A	A	A	A	A	A	C	?	A	?	?	A	?	?	?	?	?	?	T	A	G	C	?	?	A	A	A	A	C	A	A	A	A	C	
157	Peridiscaceae	?	?	A	A	A	A	A	A	A	A	A	A	A	C	C	C	A	C	A	A	A	A	A	A	C	C	A	C	C	A	A	A	C	A	A	G	A	?	C	A	A
158	Plagiopteraceae	?	?	?	?	A	A	A	A	A	C	A	A	A	A	A	C	A	A	A	A	A	A	A	A	T	T	?	?	A	A	A	C	C	A	A	C	C	A	C	A	A
159	Scyphostegiaceae	A	A	C	A	A	A	A	A	A	A	A	A	A	A	C	C	A	C	A	A	A	A	A	A	T	T	A	?	C	A	C	A	C	A	C	A	A	A	A	A	A
160	Tetrameristaceae	?	?	C	A	A	A	A	A	A	A	A	A	A	C	C	A	A	?	A	A	A	A	A	T	G	A	C	C	A	C	A	A	A	A	G	A	A	A	A	A	A
161	Tremandraceae	?	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A	C	C	A	A	A	A	C	G	A	G	C	A	A	A	A	A	A	G	A	C	A	A	C	C

Appendix 1. Continued.

dill.mat5	20	2 0 1	2 0 2	2 0 3	2 0 4	2 0 5	2 0 6	2 0 7	2 0 8	2 0 9	2 1 0	2 1 1	2 1 2	2 1 3	2 1 4	2 1 5	2 1 6	2 1 7	2 1 8	2 1 9	2 2 0	2 2 1	2 2 2	2 2 3	2 2 4	2 2 5	2 2 6	2 2 7	2 2 8	2 2 9	2 3 0	2 3 1	2 3 2	2 3 3	2 3 4	2 3 5	2 3 6	2 3 7	2 3 8	2 3 9	2 4 0
		salic	chlo	kran	leaf	vein	folia	eleo	corti	brac	K-C	peta	num	high	trimi	sepa	peta	petia	scal	peni	vena	trimi	isorr	cent	cent	poly	anth	intve	expa	conr	valv	nect	gync	carp	carp	carp	ovar	carp	degr	stipl	stipl
111	Santalales	A	A	A	C	C	C	A	?	A	C	A	G/T	A	A	C	C/G	A/C	A	A	G/T	A	C	A	A	A	C	A	A	C	A	C	C	T	G	A	A	G	A	A	A
112	Aextoxicaceae	A	A	A	?	?	?	?	A	?	A	C	A	T	A	A	A	G	A	A	A	A	A	A	?	A	A	A	A	A	A	C	C	C	A	A	A	T	A	A	A
113	Paracryphiaceae	A	A	A	C	A	A	A	?	A	A	A	G	A	A	A	A	A	A	A	G	A	C	A	A	A	C	A	A	A	A	A	A	T	T	G	A	C	A	A	A
114	Pentaphylacaceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	A	G	A	A	A	C	A	C	A	A	A	A	A	A	C	A	A	C	T	G	A	A	T	A	A	A
115	Oncothecaceae	A	A	A	C	A	A	A	?	A	C	A	T	A	A	C	G	C	A	A	C	A	C	A	A	A	A	A	A	C	A	A	?	T	G	A	A	G	A	A	A
116	Sphenostemonaceae-Aqu	A	A	A	C	A	A	A	A	A	A	A	T	A	A	A/C	G	A	A	A	C	A	C	A	A	A	A	A	C	T	A	A	C	T	C	A	A	G/T	A	A	A
117	Icacinaceae	A	A	A	C	A	A	A	?	A	C	A	T	A	A	C	G	A	A	A	C	A	C	A	A	A	C	A	A	C	A	A	C	T	G	A	A	T	A	A	A
118	Balsaminaceae	A	A	A	C	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	C	A	C	A	A	A	C	A	A	C	A	A	A	A	T	G	A	T	A	A	A
119	Fouquieriaceae	A	A	A	A	A	C	A	A	A	C	A	T	A	A	A	G	C	A	A	A	A	A	A	?	?	A	C	A	A	A	A	A	C	G	A	A	G	G	A	A	A
120	Polemoniaceae	A	A	C	A	A	A	A	A	A	C	C	T	A	A	C	G	C	A	A	C	A	C	A	A	A	C	A	A	A	C	A	C	C	G	A	A	G	T	A	A
121	Loasaceae	A	A	A	A	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	A/G	A	A/C	A/C	A/C	A/C	A	A	A	A	C	A	A	C	G/T	A/G	A	A	T	C	A	A
122	Cornales	A	A	A	C	A	C	A	A	A	C	A	G/T	A	A	C	C/G	A	A	A	C/G	A	C	A	A	A	A	A	A	A	C	C	T	G/T	A/C	A	G	A	A	A	A
123	Hydrangeaceae	A	A	A	?	?	?	A	A	A	C	A	C/T	A/C	A	C	G/T	A	A	A	C/G	A	C	A	C	A	C	A	A	A	A	C	C	T	G	A	A	G	A	A	A
124	Diapensiaceae	A	A	A	C	A	A	A	A	A	C	A/C	T	A	A	A	G	C	C	A	C	A	C	A	A	A	C	A	A	A	A	A	C	C	T	G	A	A	C	G	A	A
125	Scytopetalaceae	A	A	A	C	A	A	A	?	A	C	A	G	C	C	A	C	T	A	A	A	A	A	A	A	?	?	A	C	A	A	A	A	C	?	T	T	C	G	T	C	A	A
126	Lecythidaceae	A	A	A	C	A	A	A	A	A	A	C	A	C	C	A	A	T	A	A	A	A	A	A	A	A	C	A	C	A	A	A	A	C	C	T	T	C	A	G	A	A	A
127	Sapotaceae	A	A	A	C	C	C	A	?	A	C	A	C	C	A	A	T	C	A	A	G	A	C	A	A	A	C	A	A	A	C	A	A	C	T	T	C	A	T	C	A	A
128	Ebenaceae	A	A	A	C	A	A	A	?	A	C	A	C	C	A	C	T	C	A	A	G	A	C	A	A	A	A	A	A	A	C	A	A	A	A	T	T	C	A	G	A	A	A
129	Styracaceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	C	G	C	A	A	G	A	C	A	A	A	C	A	A	A	C	A	A	C	T	G	A	G	T	C	A	A
130	Primulales	A	A	A	C	A	A	A	A	A	C	A	T	A	A	C	G	A	A	A	C/G	A	C	A	A	A	C	A	A	A	C	A	A	C	T	G	A	A	T	A	A	A
131	Clethraceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	C	G	A	A	A	G	A	C	A	A	A	C	C	A	A	A	A	C	C	G	A	A	A	T	A	A	A
132	Actinidiaceae	A	A	A	A	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	A	A	A	A	A	A	C	A	C	A	C	A	A	C	T	G	A	G	C	A	A	A
133	Sarraceniaceae	A	A	A	?	?	?	A	?	A	C	A	T	A	A	A	G	A	A	A	G	A	C	A	C	A	A	A	A/C	A	A	A	A	C	T	G	A	A	G	A	A	A
134	Ericales	A	A	A	C	C	A	A	A	A	C	A	T	A	A	C	G	C	A	A	G	A	C	A	A	A	C	C	A	A	A	A	C	C	T	G	A	A	T	C	A	A
135	Marcgraviaceae	A	A	A	C	A	A	A	?	A	C	A	T	A	A	A	G	A	A	A	A	A	A	A	?	?	A	A	A	A	A	A	A	C	T	G	A	A	T	C	A	A
136	Cyrillaceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	C	G	A	A	A	C	A	C	A	A	A	C	A	A	C	A	A	A	C	T	G	A	A	C	A	A	A
137	Theaceae	A	A	A	C	A	C	A	A	A	A	C	C	A	A	T	A	A	A	A	A	A	A	A	C	A	C	A	A	A	C	A	A	C	T	T	C	A	G	A	A	A
138	Pittosporaceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	A	G	A	A	A	C	A	C	A	A	A	C	A	A	A	A	A	A	C	T	G	A	A	G	A	A	A
139	Araliales	A	A	A	A	A	A	A	A	A	C	A	T	A	A	A	G	A	A	A	C	A	C	A	A	A	C	A	A	A	C	A	A	C	C	T	G	A	A	G	A	A	A
140	Escalloniaceae	A	A	A	A	A	A	A	?	A	C	G	T	A	A	C	G	A	A	A	C	A	C	A	A	A	C	A	A	A	C	A	A	A	C	C	T	G	A	G	T	C	A	A
141	Dipsacales	A	A	C	C	C	A	A	A	A	C	A	T	A	A	C	G	C	A	A	C	A	C	A	A	A	C	A	A	A	C	A	A	A	C	C	T	G	A	G	T	C	A	A
142	Eucommiales	A	A	A	A	A	A	A	?	A	?	?	G	A	A	C	A	A	A	A	G	A	C	A	A	A	A	A	A	C	A	C	C	C	C	A	A	A	G	A	A	A
143	Gentianales	A	A	A	C	C	C	A	A	A	C	C	C	A	A	C	G	C	A	A	C	A	C	A	C	A	A	A	C	A	A	C	A	C	C	C	G	A	A	A	G	A	A
144	Scrophulariales	A	A	A	C	C	C	A	A	A	C	A	C	A	A	A	G	C	A	A	C	A	C	A	C	A	A	A	A	A	C	A	C	C	C	C	A	A	A	T	A	A	A
145	Solenales	A	A	C	A	A	A	A	A	A	C	A/C	T	A	A	A	G	C	A	A	C	A	C	A	A	A	C	A	A	A	C	A	C	C	C	T	G	A	G	G	A	A	A
146	Symplocaceae	A	A	A	C	A	A	A	?	A	C	A	T	A	A	C	G/T	C	A	A	A	A	A	A	C	A	C	A	A	A	C	A	C	C	T	G	A	C	T	A	A	A
147	Menyanthaceae	A	A	A	A	A	A	A	?	A	C	G	T	A	A	C	G	C	C	A	C	A	C	A	A	A	C	A	A	A	A	A	C	C	C	A	A	A	T	A	A	A
148	Campanulales	A	A	C	C	C	C	A	A	A	C	G	T	A	A	C	G	C	A	A	C	A	C	A	A	A	C	A	A	A	A	A	C	C	T	G	A	G	T	A	A	A
149	Akaniaceae	A	A	?	A	A	A	A	?	A	C	C	T	A	A	?	G	A	A	A	G	A	C	A	A	A	C	A	A	C	A	A	C	A	C	G	A	A	C	T	A	A	A
150	Bretschneideraceae	A	A	?	?	?	?	A	?	A	A	A	T	A	A	C	G	A	A	A	G	A	C	A	A	A	C	A	A	C	A	A	C	C	G/T	A/G	A	G	T	C	A	A
151	Connoraceae	A	A	A	A	A	A	A	?	A	C	A	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	C	A	C	C	C	A	A	C	G	A	A	A
152	Huaceae	A	A	A	A	A	A	A	?	A	C	G	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	A	A	A	C	T	G	A	A	T	C	A	A
153	Krameriaceae	A	A	A	C	A	C	A	?	A	C	A	T	A	A	A	G	A	A	A	C	A	C	A	A	A	C	A	A	A	A	A	A	C	C	A	A	A	T	C	A	A
154	Lactistemaceae	A	A	A	A	A	A	A	?	A	A	T	C	C	A	A	A	A	A	A	A	A	A	A	A	A	C	A	C	A	A	C	C	C	G	A	A	C	G	A	A	A
155	Leitneriaceae	A	A	A	A	A	A	A	?	T	A	A	C	C	A	A	G	A	A	A	C	A	C	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	G	A	A	A
156	Pellicieraceae	A	A	A	C	A	C	A	?	A	C	A	T	A	A	A	G	A	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A	C	C	T	G	A	A	T	A	A	A
157	Peridiscaceae	A	A	A	?	?	?	A	?	A	A	A	T	A	A	A	G	A	A	A	G	A	A	A	?	?	A	C	A	A	A	A	A	C	A	T	C	A	C	G	A	A	A
158	Plagiopteraceae	A	A	?	A	A	A	A	?	A	A	G	T	A	A	A	G	A	A	A	A	A	A	A	?	?	A	C	A	A	A	A	A	C	C	G	A	A	G	T	C	A	A
159	Scyphostegiaceae	?	A	A	A	A	A	A	?	A	A	A	C	A	C	C	A	A	A	A	T	C	C	A	A	A	A	A	C	A	A	A	A	T	T	G	A	T	C	A	A	
160	Tetramelaceae	A	A	A	A	A	A	A	?	A	C	A	G/T	A	A	A	C/G	A	A	A	C	A	C	A	A	A	A	A	A	A	A	A	C	T	C/G	A	C	T	C	A	A	
161	Tremandraceae	A	A	A	A	A	A	A	?	A	C	G	T	A	A	A	G	A	A	A	G	A	C	A	A	A	C	A	A	A	A	A	C	C	C	A	A	A	T	C	A	A

Appendix 1. Continued.

dlll.mat5	21	2 4 1	2 4 2	2 4 3	2 4 4	2 4 5	2 4 6	2 4 7	2 4 8	2 4 9	2 5 0	2 5 1	2 5 2
		plac	diffu	stigr	ovar	ovuls	ovul	micr	obtu	seec	fruit	type	cent
111	Santalales	G	A	A	A	C	A/C	C	A	T	C	T	A
112	Aextoxicaceae	T	A	A	A	C	C	C	?	A	C	T	A
113	Paracryphiaceae	G	A	A	A	T	C	G	?	T	A	A	C
114	Pentaphylacaceae	G	A	A	A	G	C	C	?	G	A	C	C
115	Oncothecaceae	G	A	C	A	G	C	G	?	C	C	T	A
116	Sphenostemonaceae-Aqu	G	A	A	A	C	C	G	C	C	C	T	A
117	Icacinaceae	G	A	A	A	G	C	G	C	A	C	T	A
118	Balsaminaceae	G	A	A	A	T	C	C	A	T	A	C	A
119	Fouquieriaceae	G/T	A	A	A	T	C	C	A	T	A	C	C
120	Polemoniaceae	G	A	A	A	T	C	G	C	T	A	C/G	A
121	Loasaceae	G/T	A	A	C	T	C	G	A	T	A	C	A
122	Cornales	G/T	A	C	C	C	C	G	A	A	C	T	A
123	Hydrangeaceae	G	G	C	C	T	C	G	?	T	A	C/G	A
124	Diapensiaceae	G	G	A	A	T	C	G	A	T	A	C	A
125	Scytopetalaceae	G	A	A	A	T	C	C	A	A	A	C	A
126	Lecythidaceae	G	A	A	C	T	C	C	A	T	C	T	A
127	Sapotaceae	G	A	A	A	C	C	?	A	C	C	T	A
128	Ebenaceae	G	A	A	C	G	C	C	A	G	A	C	A
129	Styracaceae	G	A	A	A	T	C	C	A	G	A	G	A
130	Primulales	G	G	A	C	T	C	C	A	T	A	C	A
131	Clethraceae	G	G	A	A	T	C	G	A	T	A	C	C
132	Actinidiaceae	A	A	A	A	T	C	G	A	T	A	C	?
133	Sarraceniaceae	G/T	G	A	A	T	C	?	A	T	A	C	?
134	Ericales	G/T	G	A	A	T	C	G	A	T	A	C	C
135	Marcgraviaceae	T	A	A	A	T	C	C	A	T	A	C	?
136	Cyrillaceae	G	A	A	A	T	C	G	A	C	A	C	?
137	Theaceae	G	A	A	A	T	C	C	A	T	A	C	C
138	Pittosporaceae	T	G	C	C	T	C	G	C	T	A	C	A
139	Araliales	G	A	A	C	G	C	G	C	C	C	T	C
140	Escalloniaceae	T	G	A	?	T	?	A	?	T	A	C	A
141	Dipsacales	G	A	A	C	T	C	G	C	T	A	C	A
142	Eucommiales	C	A	C	A	C	C	G	C	C	C	T	A
143	Gentianales	G	G	A	A	T	C	G	A	T	A	G	A
144	Scrophulariales	G	G	A	A	T	A/C	G	C	T	A	G	A
145	Solanales	G	A/G	A	A	T	C	G	C	T	A	G	A
146	Symplocaceae	G/T	A	A	C	T	C	G	A	T	C	T	A
147	Menyanthaceae	T	A	C	C	T	C	G	A	T	A	C	A
148	Campanulales	G	A/G	A	C	C	C	G	A	T	A	C	A
149	Akaniaceae	G	A	A	A	G	C	A	A	G	A	C	A
150	Bretschneideraceae	G	A	A	A	G	C	A	A	G	A	C	A
151	Corynocarpaceae	C	A	A	A	A	C	C	A	A	C	T	A
152	Huaceae	G	A	A	A	C	C	A	A	A	A	C	A
153	Krameriaceae	G	A	A	A	G	C	C	?	A	C	T	A
154	Lacistemaceae	T	A	A	A	G	C	A	?	T	A	C	A
155	Leitneriaceae	T	A	C	A	C	C	A	?	C	C	T	A
156	Pellicieraceae	G	A	A	A	C	C	?	?	A	C	T	A
157	Peridiscaceae	C	A	A	A	T	?	?	?	A	C	T	A
158	Plagiopteraceae	G	A	A	A	G	C	A	A	T	A	C	A
159	Scyphostegiaceae	G	A	A	A	T	C	A	A	T	A	C	A
160	Tetrameristaceae	G	A	A	A	C	C	?	A	C	C	T	A
161	Tremandraceae	G	A	A	A	G	C	A	C	T	A	C/G	A

Appendix 2. Taxon circumscriptions.

1) Ceratophyllaceae 2) Chloranthaceae 3) Nymphaeaceae 4) Amborellaceae 5) Austrobaileyaceae 6) Illiciales (Schisandraceae, Illiciaceae) 7) Winterales (Canellaceae, Winteraceae) 8) Monocotyledons 9) Aristolochianae (Saururaceae, Piperaceae, Aristolochiaceae, Lactoridaceae) 10) Laurales (Calycanthaceae, Monimiaceae, Hernandiaceae, Gyrostemonaceae, Lauraceae; Trimeniaceae are not included in this study) 11) Myristicaceae 12) Annonales (Eupomaticeae, Annonaceae) 13) Magnoliales (Himantandraceae, Degeneriaceae, Magnoliaceae) 14) Ranunculidae (Menispermaceae, Lardizabalaceae, Circaeasteraceae, Kingdoniaceae, Hydrastidaceae, Ranunculaceae, Berberidaceae, Papaveraceae) 15) Eupteleaceae 16) Platanaceae 17) Nelumbonaceae 18) Trochodendrales (Tetracentraceae, Trochodendraceae) 19) Proteaceae 20) Buxaceae 21) Sabiaceae 22) Didymelaceae 23) Myrothamnaceae 24) Berberidopsidaceae (*Berberidopsis, Streptothamnus*) 25) Gunneraceae 26) Rhabdodendraceae 27) Simmondsiaceae 28) Caryophyllales (Chenopodiaceae, Amaranthaceae, Caryophyllaceae, Nyctaginaceae, Phytolaccaceae, Achatocarpaceae, Aizoaceae, *Giesekia*, Portulacaceae, Basellaceae, Cactaceae, Didiereaceae) 29) Asteropeiaceae 30) Plumbaginaceae 31) Polygonaceae 32) Dioncophyllaceae 33) Ancistrocladaceae 34) Nepenthaceae 35) Droseraceae 36) Tamaricaceae 37) Frankeniaceae 38) Hamamelidales (Altingiaceae, Cercidiphyllaceae, Daphniphyllaceae, Hamamelidaceae) 39) Dilleniaceae 40) Vitaceae 41) Eucryphiaceae 42) Brunelliaceae 43) Cunoniales (Cunoniaceae, Davidsoniaceae, Baueraceae) 44) Paeoniaceae 45) Cephalotaceae 46) Crassulaceae 47) Saxifragales s. str. (Grossulariaceae, Haloragaceae, Penthoraceae, Saxifragaceae; without Vahliaceae, Greyiaceae, Francoaceae, Parnassiaceae, and Lepuropetalaceae) 48) Staphyleaceae 49) Elaeagnaceae 50) Rosaceae 51) Rhamnaceae 52) Faganae (Nothofagaceae, Fagaceae, Balanopaceae, Betulaceae, Myricaceae, Casuarinaceae, Rhoipteleaceae, Juglandaceae) 53) Cucurbitales (Datiscaceae, Begoniaceae, Cucurbitaceae) 54) Coriariaceae 55) Urticales (Ulmaceae, Moraceae, Cecropiaceae, Cannabaceae, Urticaceae) 56) Crossosomataceae 57) Connaraceae 58) Oxalidaceae 59) Stachyuraceae 60) Geissolomataceae 61) Geraniaceae 62) Melianthaceae 63) Fabaceae 64) Surianaceae 65) Polygalaceae 66) Rhizophoraceae 67) Zygophyllaceae (incl. Balanitaceae; without Nitrariaceae and Peganaceae) 68) Vochysiaceae 69) Myrtales (Myrtaceae, Combretaceae, Melastomataceae, Punicaceae, Lythraceae, Onagraceae, Trapaceae) 70) Rutales (Anacardiaceae, Simaroubaceae without Picramnioideae and Alvaradooideae, Rutaceae, Meliaceae, Cneoraceae) 71) Sapindales (Aceraceae, Hippocastaneaceae, Sapindaceae) 72) Celastrales (Goupiaceae, Celastraceae, Stackhousiaceae) 73) Irvingiaceae 74) Violaceae 75) Flacourtiaceae (Flacourtieae, *Oncoba*, Homalieae, Scolopieae (without *Banara*), Casearieae; without *Aphloia, Soyauxia*; latter two taxa not included in the study) 76) Kiggelariaceae {Flacourtiaceae with cyclopentenylic cyanogenic compounds (Erythrospermoideae, Pangieae, Kiggelarieae)} 77) Salicaceae 78) Elaeocarpaceae (without *Muntingia*, latter taxon not included in the study) 79) Moringaceae 80) Caricaceae 81) Passiflorales (Passifloraceae incl. Paropsieae) 82) Euphorbiales (Euphorbiaceae s.l., Pandaceae) 83) Capparales (Bataceae, Gyrostemonaceae, Koeberliniaceae, Resedaceae, Tovariaceae, Capparaceae, Brassicaceae) 84) Tropaeolaceae 85) Salvadoraceae 86) Caryocaraceae 87) Ochnaceae 88) Medusagynaceae 89) Malpighiaceae 90) Linales s. str. (Hugoniaceae, Linaceae) 91) Clusiaceae (incl. Hypericaceae) 92) Bonnetiaceae 93) Elatinaceae 94) Quiinaceae 95) Chrysobalanaceae 96) Dichapetalaceae 97) Trigoniaceae 98) Erythroxylaceae 99) Sphaerosepalaceae 100) Thymelaeaceae 101) Dipterocarpaceae 102) Sarcolaenaceae 103) Bixaceae 104) Cochlospermaceae 105) Cistaceae 106) Malvales s. str. (Tiliaceae, Sterculiaceae, Bombacaceae, Malvaceae) 107) Strasburgeriaceae 108) Podostemaceae 109) Bruniaceae 110) Balanophoraceae 111) Santalales (Olacaceae, Opiliaceae, Santalaceae, Loranthaceae, Viscaceae, Eremolepidaceae) 112) Aextoxicaceae 113) Paracryphiaceae 114) Pentaphylacaceae 115) Oncothecaceae 116) Aquifoliaceae (including *Sphenostemon*) 117) Icacinaceae 118) Balsaminaceae 119) Fouquieriaceae 120) Polemoniaceae 121) Loasaceae 122) Cornales (Alangiaceae, Nyssaceae, Davidiaceae, Mastixiaceae, Cornaceae) 123) Hydrangeaceae 124) Diapensiaceae 125) Scytopetalaceae 126) Lecythidaceae 127) Sapotaceae 128) Ebenaceae 129) Styracaceae 130) Primulales (Myrsinaceae, Theophrastaceae, Primulaceae) 131) Clethraceae 132) Actinidiaceae 133) Sarraceniaceae 134) Ericales (Epacridaceae, Ericaceae, Empetraceae, Pyrolaceae) 135) Marcgraviaceae 136) Cyrillaceae 137) Theaceae (incl. Sladeniaceae) 138) Pittosporaceae 139) Araliales (Araliaceae, Apiaceae) 140) Escalloniaceae 141) Dipsacales (Adoxaceae, Sambucaceae, Caprifoliaceae, Viburnaceae, Dipsacaceae, Valerianaceae) 142) Eucommiales (Eucommiaceae, Garryaceae, Aucubaceae) 143) Gentianales (Loganiaceae, Apocynaceae, Asclepiadaceae, Gentianaceae, Rubiaceae) 144) Scrophulariales (Buddlejaceae, Oleaceae, Bignoniaceae, Pedaliaceae, Martyniaceae, Acanthaceae, Scrophulariaceae, Callitrichaceae, Lentibulariaceae, Orobanchaceae, Verbenaceae, Lamiaceae) 145) Solanales (Convolvulaceae, Boraginaceae, Hydrophyllaceae, Solanaceae, Nolanaceae) 146) Symplocaceae 147) Menyanthaceae 148) Campanulales (Goodeniaceae, Brunoniaceae, Calyceraceae, Campanulaceae, Stylidiaceae, Asteraceae) 149) Akaniaceae 150) Bretschneideraceae 151) Corynocarpaceae 152) Huaceae 153) Krameriaceae 154) Lacistemataceae 155) Leitneriaceae 156) Pellicieraceae 157) Peridiscaceae 158) Plagiopteraceae 159) Scyphostegiaceae 160) Tetrameristaceae 161) Tremandraceae

Appendix 3. Characters and character-states.

Serology

1	serological reaction with Nelumbo antiserum (1. group)	A: absent; C: present
2	serological reaction with Nelumbo antiserum (2. group)	A: absent; C: present
3	serological reaction with Victoria antiserum	A: weak or absent; C: present
4	serological reaction with Saxifragaceae antiserum	A: weak or absent; C: present
5	serological reaction with Hydnocarpus antiserum	A: weak or absent; C: present
6	serological reaction with Passiflorales antiserum (1. group)	A: absent; C: present
7	serological reaction with Passiflorales antiserum (2. group)	A: absent; C: present

8	serological reaction with Euphorbiaceae antiserum (1. group)	A: absent; C: present
9	serological reaction with Euphorbiaceae antiserum (2. group)	A: absent; C: present
10	serological reaction with Euphorbiaceae antiserum (3. group)	A: absent; C: present
11	serological reaction with Loasaceae antiserum	A: weak or absent; C: present
12	serological reaction with Sapotaceae antiserum	A: weak or absent; C: present
13	serological reaction with Styracaceae antiserum	A: weak or absent; C: present
14	serological reaction with Primulales antiserum	A: weak or absent; C: present
15	serological reaction with Theaceae antiserum	A: weak or absent; C: present
16	serological reaction with Hydrangeaceae antiserum	A: weak or absent; C: present

Chemical compounds

17	Al accumulation	A: absent; C: present
18	amides	A: absent; C: present
19	dhurrin	A: absent; C: present
20	proteacin	A: absent; C: present
21	triglochinin	A: absent; C: present
22	taxiphyllin	A: absent; C: present
23	proacacipetalin	A: absent; C: present
24	heterodendrin	A: absent; C: present
25	cardiospermin	A: absent; C: present
26	valine- and isoleucine-derived cyanogenic compounds	A: absent; C: present
27	linamarin	A: absent; C: present
28	lotaustralin	A: absent; C: present
29	linustatin	A: absent; C: present
30	neolinustatin	A: absent; C: present
31	tyrosine-derived cyanogenic compounds	A: absent; C: present
32	prunasin	A: absent; C: present
33	sambunigrin	A: absent; C: present
34	zierin	A: absent; C: present
35	holocalin	A: absent; C: present
36	glucosinolates	A: absent; C: present
37	dihydrosterculic acid	A: absent; C: present
38	acetylenes	A: absent; C: present
39	eleostearic acid	A: absent; C: present
40	myristicin	A: absent; C: present
41	asarone	A: absent; C: present
42	sesquiterpene lactones	A: absent; C: present
43	germacrane-like compounds	A: absent; C: present
44	myoinisitol	A: absent; C: present
45	pinitol	A: absent; C: present
46	quebrachitol	A: absent; C: present
47	deutzioside	A: absent; C: present
48	cantleyoside	A: absent; C: present
49	cyclopentenylic cyanogenic glycosids	A: absent; C: present
50	simmondsin-like compounds	A: absent; C: present
51	austrobailignan	A: absent; C: present
52	kadsurin A	A: absent; C: present
53	eucommin A	A: absent; C: present
54	syringaresinol	A: absent; C: present
55	pinoresinol	A: absent; C: present
56	dihydrocubebin	A: absent; C: present
57	galbacin	A: absent; C: present
58	licarin A	A: absent; C: present
59	veraguensin	A: absent; C: present
60	prodelphinidins	A: absent; C: present
61	ellagic acid	A: absent; C: present
62	methylated ellagic acids	A: absent; C: present
63	stachyurins	A: absent; C: present
64	casuaricitin	A: absent; C: present
65	tellimagrandin I	A: absent; C: present
66	tellimagrandin II	A: absent; C: present
67	pedunculagin	A: absent; C: present
68	geraniins	A: absent; C: present
69	chlorogenic acid	A: absent; C: present
70	gallic acid	A: absent; C: present
71	epigallocatechin-3-gallate	A: absent; C: present
72	flavonoid sulphates	A: absent; C: present

73	afzelechin	A: absent; C: present
74	davidigenin	A: absent; C: present
75	biflavonoids or biflavanoids	A: absent; C: present
76	Ouratea catechins	A: absent; C: present
77	euxanthone	A: absent; C: present
78	norathyriol	A: absent; C: present
79	maclura xanthone	A: absent; C: present
80	benzylisoquinoline alkaloids	A: absent; C: present
81	roemerine	A: absent; C: present
82	anonaine	A: absent; C: present
83	liriodenine	A: absent; C: present
84	protoberberine	A: absent; C: present
85	ancistrocladine	A: absent; C: present
86	camptothecine	A: absent; C: present
87	indole alkaloids	A: absent; C: present
88	iridoid compounds	A: absent; C: present
89	secoloiridoid compounds	A: absent; C: present
90	cornin	A: absent; C: present
91	oleanolic acid & derivatives	A: absent; C: present
92	arjunolic acid & derivatives	A: absent; C: present
93	dammaranes	A: absent; C: present
94	cucurbitacins	A: absent; C: present
95	nigracin	A: absent; C: present
96	arbutin	A: absent; C: present
97	naphthoquinones	A: absent; C: present
98	rapanone	A: absent; C: present
99	plumbagin	A: absent; C: present
100	droserone	A: absent; C: present
101	anthraquinones	A: absent; C: present
102	phenanthrenes	A: absent; C: present
103	acetophenones	A: absent; C: present
104	actinidine	A: absent; C: present

Characters at cellular level

105	nitrogen-fixing nodules	A: absent; C: present
106	chromosome number $x = 7$ or $n = 6$ or $n = 8$	A: absent; C: present
107	sieve-tube plastids	A: P-type; C: S-type
108	epicuticular leaf waxes stratified	A: absent; C: present
109	epicuticular leaf waxes rod or tube shaped	A: absent; C: present
110	epicuticular leaf waxes arranged in rosettes	A: absent; C: present
111	SiO2-bodies in wood or leaf	A: absent; C: present
112	oxalate druses	A: absent; C: present
113	elongate oxalate crystals	A: absent; C: raphides; G: prismatic
114	solitary crystals	A: absent; C: present
115	crystal sand	A: absent; C: present
116	sphaerocrystals	A: absent; C: present
117	myrosine cells	A: absent; C: present
118	oil cells	A: absent; C: present
119	mucilage cavities or cells	A: absent; C: present
120	resinous cavities or cells	A: absent; C: present
121	laticiferous cavities	A: absent; C: present
122	fasciculate or stellate hairs	A: absent; C: present
123	peltate scales	A: absent; C: present
124	dendritic hairs	A: absent; C: present
125	nonglandular 2–5 armed hairs	A: absent; C: present
126	glandular scales	A: absent; C: present

Embryology

127	anther tapetum	A: amoeboid; C: secretory
128	microsporogenesis	A: successive; C: simultaneous
129	pollen organization	A: inaperturate; C: monosulcate; G: triaperturate; T: polyforate
130	type of triaperturate pollen	A: not triaperturate; C: tricolpate or polycolpate; G: tri- or polycolporate; T: triporate
131	polar pollen diameter	A: less than 20μ; C: 20–30μ; G: more than 30μ
132	triangular pollen	A: absent; C: present
133	triangular pollen, ora deepened	A: absent; C: present

134	angulaperturate pollen	A: absent; C: present
135	sexine texture	A: psilate or granulate; C: spinulose; G: reticulate; T: striate
136	type of reticulation	A: not reticulate; C: finely reticulate; G: coarsely reticulate
137	integument number	A: bitegmic; C: unitegmic
138	integumentary tapetum	A: absent; C: present
139	nucellus type	A: crassinucellar; C: weakly crassinucellar; G: tenuinucellar
140	perisperm or nucellus-derived surrounding tissue	A: absent; C: present
141	endosperm development	A: nuclear; C: cellular
142	Caryophyllad type of embryogeny	A: absent; C: present
143	Piperad type of embryogeny	A: absent; C: present
144	Asterad type of embryogeny	A: absent; C: present
Seed anatomy		
145	end of ovular or seed vascular bundle	A: chalaza; C: beyond chalaza, far from micropyle; G: near micropyle
146	aril	A: absent; C: present
147	pachychalaza	A: absent; C: present
148	sarcotesta	A: absent; C: present
149	ruminate endosperm	A: absent; C: present
150	exotestal hairs or papillae	A: absent; C: present
151	exotestal palisade	A: absent; C: present
152	theoid exotesta thickenings	A: absent; C: present
153	exotesta tanniferous or with brown contents	A: absent; C: present
154	mesotesta	A: unspecialized; C: sclerenchymatous or thickened walls
155	endotestal crystals	A: absent; C: present; G: undefined
156	endotesta	A: unspecialized cells; C: elongate cells; G: lignified, not elongate; T: tracheids
157	exotegmen	A: unspecialized cells or with lobate facets; C: sclerified or tracheidal; G: fibrous or tangentially elongate; T: as palisade layer
158	exotegmen with lobate facets	A: absent; C: present
159	bixoid exotegmen in chalazal region	A: absent; C: present
160	hypostase	A: absent; C: present
161	endosperm storage type	A: oil or proteins; C: starch; G: arabinose; T: undefined
162	endosperm haustoria	A: absent; C: present
163	embryo size	A: less than half seed length; C: bigger than in A, endosperm copious; G: bigger than in A, endosperm scanty; T: no endosperm
164	embryo form	A: straight; C: curved
165	suspensor haustoria	A: absent; C: present
Stem morphology and anatomy		
166	growth form	A: no vine; C: vine or creeping axis
167	dispersed vascular bundles	A: absent; C: present
168	anomalous secondary growth	A: absent; C: present
169	phloem stratification	A: absent; C: present
170	wedge-shaped phloem rays	A: absent; C: present
171	internal phloem	A: absent; C: present
172	cortical vascular bundles	A: absent; C: present
173	sclerenchymatous idioblasts in cortex or pericycle	A: absent; C: present
174	wood parenchyma	A: scanty or absent; C: diffuse; G: aggregate
175	fiber wall	A: thin to moderately thick; C: thick to very thick
176	fiber septation	A: absent; C: present
177	tracheids	A: absent; C: present
178	libriform fibers	A: absent; C: present
179	ray-type	A: heterogenous type I; C: heterogenous type IIa; heterogenous type IIb; T: other
180	homogenous multiseriate rays	A: absent; C: present
181	rays maximally biseriate	A: absent; C: present
182	storied wood structure	A: absent; C: present
183	vestured pits in vessel side walls	A: absent; C: present
184	vessel side pitting	A: circular, only one or two rows; C: scalariform or transitional; G: opposite; T: alternate
185	end wall perforation of pit	A: tracheids, no perforation; C: scalariform; G: mixed scalariform and simple; T: simple;
186	vessel end wall angle	A: highly oblique; C: slightly oblique; G: horizontal

187	vessel shape in transverse section	A: angular; C: slightly angular; G: oval
188	vessel aggregation	A: more than 85% solitary; C: less than 85% solitary; G: no vessels
189	dendritic pattern of vessels	A: absent; C: present
Leaf characters		
190	leaf traces	A: one; C: three; G: more than three
191	leaf arrangement	A: alternate; C: opposite; G: whorled
192	stipules	A: absent; C: present
193	glands on distal petiole	A: absent; C: present
194	leaf organization	A: simple; C: pinnate
195	stoma type	A: paracytic or tetracytic; C: encyclocytic; G: other types
196	epidermal crystals	A: absent; C: present
197	mucilaginous epidermis	A: absent; C: present
198	palmate venation	A: absent; C: present
199	craspedodromous venation	A: absent; C: present
200	leaf teeth	A: absent; C: present
201	salicoid teeth	A: absent; C: present
202	chloranthoid teeth	A: absent; C: present
203	kranz structure	A: absent; C: present
204	leaf sclereids	A: absent; C: present
205	vein terminating foliar sclereids	A: absent; C: present
206	foliar tracheoids	A: absent; C: present
Floral and fruiting characters		
207	elongated floral base	A: absent; C: present
208	cortical and axial vascular bundles in floral base	A: absent; C: present
209	bracts instead of perianth or bract-like perianth	A: absent; C: three; G: two or four; T: other numbers
210	K-C differentiation	A: not discontinuous; C: discontinuous
211	petal or tepal aestivation	A: imbricate; C: contorted; G: valvate; T: open or petals/tepals absent
212	number of calyx or tepal organs	A: zero; C: three or more than five; G: four or two; T: five
213	high calyx or tepal number	A: absent; C: six to ten; G: eleven to twenty; T: more than twenty
214	trimery in calyx or tepals	A: absent; C: present
215	sepal union	A: absent; C: present
216	petal number	A: none; C: four or two; G: five; T: six to ten
217	petal union	A: absent; C: present
218	scales on upper side of petal	A: absent; C: present
219	perianth or bract to stamen outline change	A: discontinuous; C: continuous
220	variation of isomerous patterns	A: no isomery; C: haplostemony; G: two or n isomerous or doubled whorls; T: obhaplostemony
221	trimery in androecium	A: absent; C: present
222	isomery in androecium and perianth	A: absent; C: present
223	centripetal polyandry	A: absent; C: present
224	centrifugal polyandry	A: absent; C: present
225	polyandry associated with outer stamen pairs	A: absent; C: present
226	anther to stamen length-ratio	A: more than half; C: less than half
227	inverted anthers	A: absent; C: present
228	expanded stamen	A: absent; C: present
229	connective tip	A: not prolonged; C: prolonged not as in G or T; G: membranaceous; T: expanded or massive
230	valvate anther dehiscence	A: absent; C: present
231	disk	A: absent; C: present
232	gynoecium position	A: not antepetalous (or antetepalous); C: antepetalous or antetepalous, not oblique; G: oblique
233	carpel number I	A: one; C: two; G: three; T: more than three
234	carpel number II	A: three or less; C: four; G: five; T: more than five
235	carpel number III	A: five or less; C: six to ten; G: eleven to twenty; T: more than twenty
236	ovary to carpel length-ratio	A: more than 1:2; C: 1:2 to 1:3; G: less than 1:3
237	carpel union	A: unicarpellate or totally apocarpous; C: ovary partially fused; G: styles free or partially fused; T: styles fully fused
238	degree of syncarpy	A: not totally syncarpous; C: totally syncarpous
239	stipitate free carpels or stipitate unicarpellate fruits	A: absent; C: present
240	stigmatic crest	A: absent; C: present

241	placentation	A: marginal or laminar on apocarpous carpels; C: apical; G: axile, free central or basal; T: parietal
242	diffuse placenta	A: absent; C: laminar diffuse; T: protruding diffuse
243	stigma decurrent	A: absent; C: present
244	ovary position	A: superior; C: inferior
245	ovule to carpel number	A: less than one; C: one; G: two; T: more than two
246	ovule curvature	A: orthotropous; C: anatropous or campylotropous
247	micropyle formation	A: outer or both integuments; C: inner integument; G: by the only integument; T: no integuments
248	obturator	A: absent; C: present
249	seed to carpel number	A: less than one; C: one; G: two; T: more than two
250	fruit type	A: dehiscent fruit; C: indehiscent fruit
251	type of dehiscent fruit	A: follicle, pod or ventricidal capsule; C: capsule types other than in A and T; G: septicidal capsule; T: indehiscent fruit or schizocarp
252	central column in fruit	A: absent; C: present

Data errors in non-molecular matrix that could not be corrected

Amborellaceae: character 129, A/C instead of A (we became aware of Sampson, 1993, too late to include this polymorphism); Myristicaceae: character 251, A instead of G; Fabaceae: character 105, C instead of A; Myrtales: character 87, C instead of A

Appendix 4. Character definitions.

Characters and character-states requiring further explanation are given below.

Characters on cellular level

122	fasciculate or stellate hairs	: definition following Metcalfe & Chalk, 1950
123	peltate scales	: definition following Metcalfe & Chalk, 1950
124	dendritic hairs	: definition following Metcalfe & Chalk, 1950
125	nonglandular 2–5 armed hairs	: definition following Metcalfe & Chalk, 1950
126	glandular scales	: definition following Metcalfe & Chalk, 1950

Seed anatomy

152	theoid exotesta thickenings	: exotesta showing thickenings on radial and inner tangential walls, but not on outer tangential walls (cf. Huber, 1991)
159	bixoid exotegmen in chalazal region	: seeds with exotegmen organized as palisade layer, the latter showing a typical inward curving in the chalazal region associated with a hypostase plug differentiated into core and annulus region (see Nandi, 1998a)

Stem morphology and anatomy

175	fiber wall	: thin to moderately thick means sum of wall-thickness is smaller than fiber lumen diameter

Leaf characters

199	craspedodromous venation	: secondary venation running into leaf teeth
201	salicoid teeth	: leaf teeth showing a proximally rounded hyaline gland with concave gland body in herbarium specimens; see also Doyle & Hickey, 1975
202	chloranthoid teeth	: definition following Doyle & Hickey, 1975
205	vein terminating foliar sclereids	: definition following Rao, 1991
206	foliar tracheoids	: definition following Rao, 1991

Floral and fruiting characters

225	polyandry associated with outer stamen pairs	: definition following Ronse Decraene, 1992
228	expanded stamen	: thecae of anthers widely separated or stamen laminar
230	valvate anther dehiscence	: definition following Endress, 1994d
232	gynoecium position	: defined as antetepalous if one carpel is in line with a median tepal or petal
240	stigmatic crest	: broad, decurrent stigma, deeply furrowed into two parts
242	diffuse placenta	: definition following Endress, 1994a

243	stigma decurrent	: stigmatic surface unilaterally running down more than three times the stigma lobe breadth

Appendix 5. Procedures of character-state assignment.

The procedures for assigning character-states to matrix fields are indicated in the overview given below. In characters that are not listed, presence was favored over absence (monocots: presence only favored if occurring in *Acorus*, Arales, Arecales, or Alismatidae; the restriction to the presumed basal monocot clades reduces parallelisms).

Serology

Characters 1–16: strongest serological reaction > [">" means favored]

Chemical compounds

Characters 17–114: Presence of a chemical compound > absence

Characters at cellular level

107	sieve-tube plastids	Both types equally >, character-state of presumed basal members > in Winterales, Magnoliales, Laurales

Embryology

127	anther tapetum	Both types equally >
128	microsporogenesis	Both types equally >
129	pollen organization	Character-state of presumed basal members >
130	type of triaperturate pollen	Character-state of presumed basal members >
131	polar pollen diameter	least polar pollen diameter >
135	sexine texture	Character-state of presumed basal members >
136	type of reticulation	Character-state of presumed basal members >
137	integument number	A > C
138	integumentary tapetum	Character-state of presumed basal members >
139	nucellus type	A > C > G
141	endosperm development	Both types equally >

Seed anatomy

145	end of ovular or seed vascular bundle	G > C > A
154	mesotesta	C > A
156	endotesta	T, G, and C > A
157	exotegmen	T, G, and C > A
161	endosperm storage type	All types equally >
163	embryo size	A > C > G > T
164	embryo form	A > C

Stem morphology and anatomy

166	growth form	Both types equally >
168	anomalous secondary growth	Character state of presumed basal members >
171	internal phloem	Character state of presumed basal members >
174	wood parenchyma	A > C > G
175	fiber wall	A > C
176	fiber septation	A > C
178	libriform fibers	Absence > presence
179	ray-type	A > C > G > T
180	homogenous multiseriate rays	Character state of presumed basal members >
181	rays maximally biseriate	Character state of presumed basal members >
184	vessel side pitting	A and C > G > T
185	end wall perforation of pit	A > C > G > T
186	vessel end wall angle	A > C > G
187	vessel shape in transverse section	A > C > G
188	vessel aggregation	G > A > C

Leaf characters

190	leaf traces	Character state of presumed basal members >
191	leaf arrangement	Character state of presumed basal members >
194	leaf organization	Both types equally >
195	stoma type	Character state of presumed basal members >
200	leaf teeth	Character state of presumed basal members >

Floral and fruiting characters

209	bracts instead of perianth or bract-like perianth	Character state of presumed basal members >

210	K-C differentiation	A > C
211	petal or tepal aestivation	Character state of presumed basal members >
212	number of calyx or tepal organs	Character state of presumed basal members >
213	high calyx or tepal number	Character state of presumed basal members >
214	trimery in calyx or tepals	Character state of presumed basal members >
215	sepal union	Absence > presence
216	petal number	Character state of presumed basal members >
217	petal union	Absence > presence
219	perianth or bract to stamen outline change	C > A
220	variation of isomerous patterns	Character state of presumed basal members >
221	trimery in androecium	Character state of presumed basal members >
222	isomery in androecium and perianth	Character state of presumed basal members >
223	centripetal polyandry	Character state of presumed basal members >
224	centrifugal polyandry	Character state of presumed basal members >
226	anther to stamen length-ratio	Character state of presumed basal members >
229	connective tip	T > G and C > A
231	disk	Character state of presumed basal members >
232	gynoecium position	A > C and G
233	carpel number I	Character state of presumed basal members >
234	carpel number II	Character state of presumed basal members >
235	carpel number III	Character state of presumed basal members >
236	ovary to carpel length-ratio	A > C > G
237	carpel union	A > C > G > T
238	degree of syncarpy	A > C
241	placentation	Character state of presumed basal members >
242	diffuse placenta	Character state of presumed basal members >
244	ovary position	A > C
245	ovule to carpel number	T > G > C > A
246	ovule curvature	Character state of presumed basal members >
247	micropyle formation	Character state of presumed basal members >
249	seed to carpel number	T > G > C > A
250	fruit type	Character state of presumed basal members >
251	type of dehiscent fruit	A > C and G > T

Appendix 6. Sources.

Literature used for taxon delimitations and for finding character-states.

Taxon delimitations

Albert et al., 1992; Alverson et al., 1994; Baas, 1972, 1975; Carpenter & Dickison, 1976; Chase & Swensen, 1995; Chase et al., 1993, 1995; Conti et al., 1993; Corner, 1976; Cronquist, 1981, 1983; Dahlgren, 1980, 1983; Dahlgren & Clifford, 1982; Dahlgren & Thorne, 1984; Dahlgren et al., 1985; Downie & Palmer, 1994; Duvall et al., 1993b; Engler & Prantl (eds.), 1887–1914, 1924–1995; Fernando et al., 1995; Gadek et al., 1992; Geetha et al., 1993; Gustafsson & Bremer, 1995; Hegnauer, 1962–1994; Huber, 1991; Hutchinson, 1964/1967, 1973; Kolbe & John, 1979a, b; Kron & Chase, 1993; Lemke, 1988; Melchior (ed.), 1964; Miller, 1975; Morgan & Soltis, 1993; Olmstead et al., 1992, 1993; Price & Palmer, 1993; Qiu et al., 1993; Rodman et al., 1993; Savolainen et al., 1994; Soltis et al., 1995b; Sutter & Endress, 1995; Swensen et al., 1994; Takhtajan, 1966, 1987; Thorne, 1983, 1992; van Vliet & Baas, 1984; Xiang et al., 1993

Serology

Fairbrothers, 1966; Grund & Jensen, 1981; Hillebrand & Fairbrothers, 1966, 1970; Jensen & Greven, 1984; John & Kolbe, 1980; Kolbe & John, 1979a, b; Simon, 1970, 1971; Vogel, 1986

Chemical compounds

Arora & Metha, 1981; Barron et al., 1988; Bliss et al., 1968; Bohm & Chan, 1992; Brüning & Wagner, 1978; Crossley & Djerassi, 1962; Deyama et al., 1985; Durant & Zenk, 1974; Filho et al., 1985; Fieser & Chamberlain, 1948; Gibbs, 1974; Gildemeister & Hoffmann, 1956; Harborne, 1969; Harborne & Baxter, 1993; Hayashi et al., 1980; Hegnauer, 1962–1994; Keller, 1982; Lavault & Bruneton, 1980; Le Quesne et al., 1980; Lebreton & Bouchez, 1967; McAlpine et al., 1968; Murai et al., 1985; Rao & Alvarez, 1982; Sethi et al., 1976; Sévenet et al., 1971; Smith et al., 1980; Thieme & Benecke, 1966, 1970; Uesato et al., 1986; Zenk et al., 1969

Characters on cellular level

Baas, 1972, 1975, 1984; Baas et al., 1979; Behnke, 1975, 1977, 1981, 1985; Carpenter & Dickison, 1976; Cronquist, 1981, 1983; Dickison, 1978, 1981, 1990; Dickison & Baas, 1977; Ditsch & Barthlott, 1994; Ehrendorfer et al., 1984; Engler & Prantl (eds.), 1887–1914, 1924–1995; Fehrenbach & Barthlott, 1988; Franceschi & Horner, 1980; Goldblatt & Dorr, 1986; Goldblatt & Johnson (eds.), 1981/1984/1985/1988/1990/1991/1994; Gottwald & Parameswaran, 1966, 1967, 1968; Hennig et al., 1994; Huber, 1991; Hutchinson, 1973; Keng, 1962; Metcalfe, 1956, 1962, 1987; Metcalfe & Chalk, 1950, 1988/1989; Miller, 1975; Proctor, 1955; Puff & Weber, 1976; Ricci, 1957; Schmid, 1964; Solereder, 1899/1908; Solereder & Meyer, 1928; Sprent & McKey (eds.), 1994; Theisen & Barthlott, 1994

Embryology

Baas, 1972; Barth, 1965; Batygina et al., 1985a, b, c; Bhandari, 1971; Boesewinkel, 1985, 1994; Boesewinkel

& Bouman, 1980; Carpenter & Dickison, 1976; Chiarugi, 1925; Chiarugi & Francini, 1930; Chopra & Harjinder, 1965; Corner, 1976; Cronquist, 1981; Davis, 1966; Dickison, 1979, 1981, 1986, 1990; Dickison & Baas, 1977; Dickison et al., 1982; Endress, 1993a, b, c; Erdtman, 1952, 1958; Gavrilova, 1993; Gutzwiller, 1961; van Heel, 1967, 1984; Heo & Tobe, 1994; Hideux & Ferguson, 1976; Huang Tseng-Chieng, 1972; Huber, 1991, 1993; Huynh, 1969; Jäger-Zürn, 1966; Johri, 1970; Johri & Kak, 1954; Johri et al., 1967, 1992; Kamelina et al., 1981, 1983; Kapil & Bhatnagar, 1991; Kapil & Maheshwari, 1965; Kaur, 1969; Keating, 1972, 1975; Köhler, 1994; Kubitzki, 1993a, b, c; Les, 1988, 1993; Maguire & Ashton, 1980; Mauritzon, 1935, 1936; Maury et al., 1975; Melchior (ed.), 1964; Netolitzky, 1926; Philipson, 1993; Prance, 1968, 1972; Puff & Weber, 1976; Rutishauser, 1997; Sáenz de Rivas, 1979; Satabié, 1974; Schmid, 1964; Schnarf, 1931; Souèges, 1937; Takhtajan (ed.), 1985/1988/1991; Tang, 1994; Thanikaimoni, 1986; Tobe & Peng, 1990; Tobe & Raven, 1995; Todzia, 1993; Tsou, 1994; Ukraintseva, 1993; Vijayaraghavan & Dhar, 1976; Walia & Kapil, 1965; Walker & Walker, 1984; Williamson & Schneider, 1993; Wu Cheng-Yih & Kubitzki, 1993; Yoffe, 1962; Zhang Zhi-Yu, 1987

Seed anatomy

Baas, 1972; Blank, 1939; Boesewinkel, 1985, 1994; Boesewinkel & Bouman, 1980; Corner, 1976; Cronquist, 1981; Dickison & Baas, 1977; Endress, 1980, 1987; Engler & Prantl (eds.), 1887–1914, 1924–1995; van Heel, 1967; Huber, 1991; Keng, 1962; Mc Nair, 1930; Netolitzky, 1926; Seubert, 1993; Takhtajan (ed.), 1985/1988/1991; Thanikaimoni, 1986; Tobe & Peng, 1990; Tobe & Raven, 1995; Wojciechowska, 1969

Stem morphology and anatomy

Baas, 1969, 1972, 1975, 1984; Baas & Werker, 1981; Baas et al., 1979; Bailey, 1980; Bailey, 1933, 1957; Bailey & Swami, 1948; Baretta-Kuipers, 1976; Berg, 1977; Blank, 1939; Canright, 1955; Carlquist, 1964, 1976, 1977, 1981, 1984a, b, c, d, 1988a, b, 1990, 1993; Carlquist & Hoekman, 1985; Carpenter & Dickison, 1976; Cronquist, 1981; Dahlgren & Thorne, 1984; Dechamps, 1979–1985; Decker, 1966; Den Outer & Vooren, 1980; Dickison, 1969, 1978, 1981, 1986, 1990; Dickison & Baas, 1977; Endress, 1993a, b, c; Garratt, 1933; Gottwald & Parameswaran, 1966, 1967, 1968; Gutzwiller, 1961; Heimsch, 1942; Hekking, 1988; Huber, 1993; Humphrey, 1935; Ilic, 1991; Keefe & Moseley, 1978; Keng, 1962; Kessler, 1993; Kribs, 1935; Kubitzki, 1993a, b, c; Les, 1993; Maguire & Ashton, 1980; Maguire et al., 1972; Mennega, 1982; Metcalfe, 1952, 1956, 1962, 1987; Metcalfe & Chalk, 1950, 1988/1989; Meylan & Butterfield, 1978; Miller, 1975; Philipson, 1993; Piccioli, 1901; Prance, 1972; Prance & da Silva, 1973; Puff & Weber, 1976; Record, 1933; Schmid, 1964; Schweingruber, 1990; Shiklina, 1977; Solereder, 1899/1908; Takahashi, 1985; Takhtajan, 1966; Taylor, 1972; Tomlinson, 1961; Vestal, 1937; van Vliet & Baas, 1984; Whalen, 1987; Williamson & Schneider, 1993

Leaf characters

Arber, 1925; Baas, 1969, 1972, 1975, 1984; Baas et al., 1979; Bedell, 1981; Berg, 1977; Blank, 1939; Canright, 1955; Capuron, 1974; Carpenter & Dickison, 1976; Crane, 1989; Crane et al., 1993; Cronquist, 1981; Cuatrecasas, 1985; Dahlgren & Thorne, 1984; Dickison, 1978, 1981, 1990; Dickison & Baas, 1977; Dilcher & Crane, 1984; Engler & Prantl (eds.), 1887–1914, 1924–1995; Heywood (ed.), 1978; Hufford, 1992; Humphrey, 1935; Hutchinson, 1964/1967, 1973; Keng, 1962; Klucking, 1992; Kostermans, 1985; Les, 1993; Levin, 1986; Maguire & Ashton, 1980; Melchior (ed.), 1964; Metcalfe, 1956, 1962, 1987; Metcalfe & Chalk, 1950, 1988/1989; Prance, 1972; Prance & da Silva, 1973; Puff & Weber, 1976; Rao, 1991; Schmid, 1964; Sinnott, 1914; Takhtajan, 1966; Thanikaimoni, 1986; Tomlinson, 1961

Floral and fruiting characters

Airy Shaw, 1951; Baas, 1972; Baas et al., 1979; Baillon, 1873; Batygina et al., 1985a, b, c; Bausch, 1938; Bayer & Hoppe, 1990; Berg, 1977; van Beusekom, 1971; Blank, 1939; Boureau, 1958; Brizicky, 1964; Carpenter & Dickison, 1976; Corner, 1946; Crane et al., 1993; Cronquist, 1981, 1983; Cuatrecasas, 1985; Dahlgren & Rao, 1969; Dahlgren et al., 1985; Dickison, 1969, 1978, 1981, 1986, 1990; Dickison & Baas, 1977; Dilcher & Crane, 1984; Drinnan et al., 1991; Drude, 1891a, b; Endress, 1986, 1989, 1993a, b, c, 1994a, b, c, d; Endress & Stumpf, 1991; Engler, 1930; Engler & Prantl (eds.), 1887–1914, 1924–1995; Friis, 1984; Gagnepain et al. (eds.), 1907–1942; Gore, 1935; Gutzwiller, 1961; Haber, 1959, 1961, 1966; van Heel, 1966, 1967, 1984; Heinig, 1951; Hekking, 1988; Heo & Tobe, 1994; Heywood (ed.), 1978; Hirmer, 1918; Huber, 1991, 1993; Hufford, 1992; Hufford & Endress, 1989; Hutchinson, 1964/1967, 1973; Jäger-Zürn, 1966; Janchen, 1909; Johri et al., 1992; Kamelina et al., 1981; Kamelina et al., 1983; Kanis, 1968; Keating, 1972; Keng, 1962; Kessler, 1993; Kobuski, 1951; Kostermans, 1985; Kubitzki, 1993a, b, c; Leenhouts, 1956; Les, 1993; Letouzey, 1961; Maguire & Ashton, 1980; Martius (ed.), 1840–1906; Melchior (ed.), 1964; Metcalfe, 1956; Payer, 1857; Philipson, 1993; Pilger, 1925a, b; Prance, 1972; Prance & da Silva, 1973; Puff & Weber, 1976; Rendle et al., 1921; Ronse Decraene, 1989, 1992; Ronse Decraene & Smets, 1992; Rutishauser, 1997; Sandwith, 1962; Sattler, 1973; Saunders, 1937; Saunders, 1937–1939; Schaeppi, 1953; Schmid, 1964; Stearn, 1946; Sutter & Endress, 1995; Takhtajan, 1966, 1987; Thanikaimoni, 1986; Tobe & Peng, 1990; Tobe & Raven, 1995; Todzia, 1993; Veldkamp, 1984; Williamson & Schneider, 1993; Wilson, 1965; Woon & Keng, 1979; Wu Cheng-Yih & Kubitzki, 1993

Hostplants of fungi and butterflies (not included in computation)

Ackery, 1988, 1991; DeVries, 1987; Farr et al., 1989; Pierre, 1984

Appendix 7. Table of *rbc*L taxa.

Table of taxa samples for *rbc*L. These are arranged alphabetically by families (mostly according to Cronquist, 1981).

Species	Family	Voucher/source	Literature citation§	GenBank accession
Actinidia chinensis Planch.	Actinidiaceae	*Kron 2117*, NCU	Albert et al., 1992	L01882
Aextoxicon punctatum Ruiz & Pav.	Aextoxicaceae	*Chase 959*, K	this paper	
Akania bidwillii (Hogg) Mabb.	Akaniaceae	*Fernando & Quinn 21606*, UNSW	Gadek et al., 1992	L12568
Amborella trichopoda Baill.	Amborellaceae	*Thien 500*, NO	Qiu et al., 1993	L12628
Ancistrocladus korupensis D. W. Thomas & Gereau	Ancistrocladaceae	*Gereau et al. 5203*, MO	this paper	
Asimina triloba (L.) Dunal	Annonaceae	*Qiu 15*, NCU	Qiu et al., 1993	L12631
Ilex crenata Thunb.	Aquifoliaceae	*Chase 119*, NCU	Albert et al., 1992	L01928
Acorus calamus L.	Araceae	*French 232*, CH	Duvall et al., 1993a	M91625
Aralia spinosa L.	Araliaceae	*Plunkett 1371*, WS	Chase et al., 1993	L11166
Asarum canadense L.	Aristolochiaceae	none	Chase et al., 1993	L14290
Asteropeia microsteira	Asteropeiaceae	*Civeyrel s.n.*, K	this paper	
Austrobaileya scandens C. T. White	Austrobaileyaceae	*Qiu 90030*, NCU	Qiu et al., 1993	L12632
Impatiens capensis Meerb.	Balsaminaceae	*Chase 114*, NCU	Chase et al., 1993	
Mahonia bealei (Fortune) Carr.	Berberidaceae	*Qiu 74*, NCU	Qiu et al., 1993	L12657
Berberidopsis corallina Hook. f.	Berberidopsidaceae	*Chase 555*, K	this paper	
Bixa orellana L.	Bixaceae	*Alverson s.n.*, WISC	this paper	
Brassica campestris L.	Brassicaceae	unknown	Olmstead et al., 1992	
Bretschneidera sinensis Hemsl.	Bretschneideraceae	*Leu & Lin 726*, WIS	Chase et al., 1993	M95753
Berzelia lanuginosa (L.) Brongn.	Bruniaceae	*Price s.n.*, Ind.	Olmstead et al., 1993	L14391
Pachysandra procumbens Michx.	Buxaceae	*Chase 207*, NCU	Chase et al., 1993	
Chimonanthus praecox (L.) Link	Calycanthaceae	*Qiu 62*, NCU	Qiu et al., 1993	L12639
Lobelia erinus L.	Campanulaceae	*Jansen 989*, MICH	Albert et al., 1992	L01931
Canella winterana (L.) Gaertn.	Canellaceae	*Qiu 90017*, NCU	Qiu et al., 1993	
Viburnum acerifolia L.	Caprifoliaceae	*Jansen 910*, MICH	Olmstead et al., 1992	L01959
Carica papaya L.	Caricaceae	Wisconsin BG	Rodman et al., 1993	M95671
Caryocar glabrum Pers.	Caryocaraceae	*Mori 22997* NY	this paper	
Euonymus alatus (Thunb.) Siebold	Celastraceae	*Chase 137*, NCU	Chase et al., 1993	L13184
Cephalotus follicularis Labill.	Cephalotaceae	*Chase 147*, NCU	Albert et al., 1992	L01894
Ceratophyllum demersum L.	Ceratophyllaceae	*Les s.n.*, CONN	Les et al., 1991	M77030
		Qiu 91027, NCU	Qiu et al., 1993	
Spinacia oleracea L.	Chenopodiaceae	unknown	Zurawski et al., 1981	J01443
Chloranthus japonicus Siebold	Chloranthaceae	*Chase 204*, NCU	Qiu et al., 1993	L12640
Chrysobalanus icaco L.	Chrysobalanaceae	*Fairchild Trop. G 76-311*	Morgan & Soltis, 1993	L11178
Helianthemum grandiflorum (Scop.) DC.	Cistaceae	*Chase 525*, K	this paper	

Appendix 7. Continued.

Species	Family	Voucher/source	Literature citation§	GenBank accession
Clethra alnifolia L.	Clethraceae	*Kron 1884*, NCU	Kron & Chase, 1993	L12609
Clusia gundlachii Stahl	Clusiaceae	*Chase 341*, NCU	Fay et al., 1997	Z75673
Quisqualis indica L.	Combretaceae	*W. R. Anderson s.n.*, MICH	Albert et al., 1992	L01948
Connarus conchocarpus F. Muell.	Connaraceae	*Uhl 601*, BH	Morgan et al., 1994	U06798
Coriaria myrtifolia L.	Coriariaceae	*Chase 245*, NCU	Albert et al., 1992	L01897
Cornus walteri Wangerin	Cornaceae	Arnold Arb. 414-67-A	Xiang et al., 1993	L11220
Corynocarpus laevigata J. R. Forst. & G. Forst.	Corynocarpaceae	no voucher	this paper	
Dudleya viscida (S. Watson) Moran	Crassulaceae	Huntington BG 62801	Morgan & Soltis, 1993	L11182
Crossosoma californicum Nutt.	Crossosomataceae	Rancho Santa Ana BG	Morgan & Soltis, 1993	L11179
Cucurbita pepo L.	Cucurbitaceae	none	Chase et al., 1993	L21938
Ceratopetalum gummiferum Small	Cunoniaceae	*Keller 2135*, CAS	Albert et al., 1992	L01895
Cyrilla racemiflora L.	Cyrillaceae	*Kron s.n.*, NCU	Albert et al., 1992	L01900
Diapensia lapponica L.	Diapensiaceae	*Hills 89018*, NCU	Kron & Chase, 1993	L12612
Dichapetalum macrocarpon Engl.	Dichapetalaceae	*Fison s.n.*, K	this paper	
Didymeles perrieri Leandri	Didymelaceae	*Leandi s. n.*, MO	this paper	
Dillenia indica L.	Dilleniaceae	*Chase 234*, NCU	Albert et al., 1992	L01903
Triphyophyllum peltatum (Hutchison & Dalziel) Airy Shaw	Dionocophyllaceae	*Chase 663*, K	this paper	
Shorea zeylanica (Thwaites) Ashton	Dipterocarpaceae	*Dayanandan D6*, GF	Chase et al., 1993	
Drosera binata Labill.	Droseraceae	*Williams D41*, LVC	Williams et al., 1994	L01911
Diospyros virginiana L.	Ebenaceae	*Kron 3004*, NCU	Kron & Chase, 1993	L12613
Hippophae salicifolia	Elaeagnaceae	*Chase 856*, K	this paper	
Elaeocarpus reticulatus	Elaeocarpaceae	*Quinn s.n.*, UNSW	this paper	
Erica australis L.	Ericaceae	RBG Edinburgh 781912	Chase et al., 1993	L13183
Escallonia coquimbensis Remy	Escalloniaceae	U. Calif. BG 52.1333	Morgan & Soltis, 1993	L11183
Eucommia ulmoides Oliv.	Eucommiaceae	*Qiu 91024*, NCU	Albert et al., 1992	L01917
Eucryphia lucida Druce	Eucryphiaceae	Strybing Arb. 86-0250	Albert et al., 1992	L01918
Jatropha interregima Jacq.	Euphorbiaceae	*Fairchild Trop. G 63169A*	this paper	
Euptelea polyandra Siebold & Zucc.	Eupteleaceae	*Qiu 90026*, NCU	Qiu et al., 1993	L12645
Medicago sativa L.	Fabaceae	unknown	Aldrich et al., 1986	
Nothofagus dombeyi (Mirb.) Oerst.	Fagaceae	U Washington BG	Chase et al., 1993	L13350
Poliothyrsis sinensis Hook. f.	Flacourtiaceae	*K. Wurdack s.n.*, NCU	this paper	
Frankenia pulverulenta L.	Frankeniaceae	*Collenette 6/93*, K	this paper	
Fouquieria columnaris Kellogg	Fouquieriaceae	U of California, Irvine, Arb.	Morton et al., 1997	

Appendix 7. Continued.

Species	Family	Voucher/source	Literature citation§	GenBank accession
Trichadenia zeylanica Thwaites	Kiggelariaceae	*Chase 1289*, K	this paper	
Geissoloma marginatum (L.) A. Juss.	Geissolomataceae	unknown	Savolainen, unpubl.	
Gentiana procera Holm	Gentianaceae	none	Olmstead et al., 1993	L14398
Geranium grandiflorum Gilib.	Geraniaceae	*Price s.n.*, IND	Albert et al., 1992	L01920
Gunnera hamiltonii Kirk ex W. S. Ham.	Gunneraceae	*Chase 562*, K	this paper	
Hamamelis mollis Oliv.	Hamamelidaceae	*Qiu 91035*, NCU	Albert et al., 1992	L01922
Hua gabonii Pierre ex De Wild.	Huaceae	*Wieringa 3177*, WAG	this paper	
Hydrangea macrophylla Torr.	Hydrangeaceae	*Morgan 2150*, WS	Morgan & Soltis, 1993	L11187
Icacina mannii Oliv.	Icacinaceae	*van Setten 460*, WAG	this paper	
Illicium parviflorum Michx. ex Vent.	Illiciaceae	*Qiu 83*, NCU	Qiu et al., 1993	L12652
Irvingia malayana Oliv. ex Benn.	Irvingiaceae	*Simpson 2638*, K	Fernando et al., 1995	
Koeberlinia spinosa Zucc.	Koeberliniaceae	*Al-Shehbaz s.n.*, WIS	Rodman et al., 1993	L14600
Krameria lanceolata Torr.	Krameriaceae	*Simpson 88-05-1-1*, MICH Chase et al., 1993		
Lacistema aggregatum Rusby	Lacistemataceae	*Pennington et al. 583*, K	this paper	
Leitneria floridana Chapm.	Leitneriaceae	*Qiu 91033*, NCU	Chase et al., 1993	
Couroupita guianensis Aublet	Lecythidaceae	RBG Kew 1960-43401	Morton et al., 1997	
Linum perenne L.	Linaceae	*Chase 111*, NCU	Fay et al., 1997	Z75681
Magnolia hypoleuca Siebold & Zucc.	Magnoliaceae	*Qiu 24*, NCU	Qiu et al., 1993	L12655
Byrsonima crassifolia (L.) Kunth	Malpighiaceae	*Fairchild Trop. G 81680*, MICH	Albert et al., 1992	L01892
Gossypium robinsonii F. Muell.	Malvaceae	*Wendel s.n.*, ISC	Chase et al., 1993	L13186
Marcgravia rectiflora Triana & Planch.	Marcgraviaceae	*Chase 331*, NCU	this paper	
Medusagyne oppositifolia Baker	Medusagynaceae	*Chase 670*, K	Fay et al., 1997	Z75670
Bersama lucens Szyszyl.	Melianthaceae	*Chase 1125*, K	this paper	
Menyanthes trifoliata L.	Menyanthaceae	none	Olmstead et al., 1993	L14006
Morus alba L.	Moraceae	none	Albert et al., 1992	L01933
Moringa oleifera Lam.	Moringaceae	*Iltis 30501*, WIS	Rodman et al., 1993	L11359
Knema latericia Elmer	Myristicaceae	*Qiu 91041*, NCU	Qiu et al., 1993	L12653
Maesa myrsinioides Leveille	Myrsinaceae	*Chase 309*, K	this paper	
Myrothamnus sp.	Myrothamnaceae	*Hoot s.n.*, F	this paper	
Nelumbo lutea (Willd.) Pers.	Nelumbonaceae	*Les s.n.*, CONN	Les et al., 1991	M77032
		Qiu 91028, NCU	Qiu et al., 1993	
Nepenthes alata Blanco	Nepenthaceae	*Chase 145*, NCU	Albert et al., 1992	L01936
Nymphaea odorata Aiton	Nymphaeaceae	*Les s.n.*, CONN	Les et al., 1991	M77035
		Qiu 91029, NCU	Qiu et al., 1993	

Appendix 7. Continued.

Species	Family	Voucher/source	Literature citation§	GenBank accession
Ochna multiflora DC.	Ochnaceae	*Chase 229*, NCU	Chase et al., 1993	
Schoepfia schreberi J. F. Gmel.	Olacaceae	*Nickrent 2599*, ILL	Morgan & Soltis, 1993	L11205
Oxalis dillenii Jacq.	Oxalidaceae	*Price s.n.*, IND	Albert et al., 1992	L01938
Paeonia tenuifolia L.	Paeoniaceae	*Kron 2115*, NCU	Chase et al., 1993	L13187
Passiflora quadrangularis L.	Passifloraceae	*Kron 3000*, NCU	Albert et al., 1992	L01940
Pelliciera rhizophora Planchon & Triana	Pellicieraceae	*Pennington et al. 586*, K	this paper	
Pittosporum japonicum Hort. ex C. Presl	Pittosporaceae	*Rieseberg s.n.*, RSA	Morgan & Soltis, 1993	L11202
Plagiopteron suaveolens Griff.	Plagiopteridaceae	*Chase 1335*, K	this paper	
Platanus occidentalis L.	Platanaceae	*Qiu P90005*, NCU	Albert et al., 1992	L01943
Plumbago capensis Thunb.	Plumbaginaceae	unknown	Giannasi et al., 1992	M77701
Gilia aggregata (Pursh) Spreng.	Polemoniaceae	*Chase 970*, K	this paper	
Polygala cruciata L.	Polygalaceae	*Chase 155*, NCU	Albert et al., 1992	L01945
Rheum × *cultorum* Thorsrud & Reisaeter	Polygonaceae	unknown	Giannasi et al., 1992	M77702
Lambertia inermis R. Br.	Proteaceae	Natl. Trop. BG, Hawaii	Morgan & Soltis, 1993	L11190
Quiina pteridophylla (Radlk.) Pires	Quiinaceae	*Pennington 13846*, K	Fay et al., 1997	Z75689
Rhabdodendron amazonicum Huber	Rhabdodendraceae	*Ribéiro 1187*, K	this paper	
Rhamnus cartharticus L.	Rhamnaceae	*Chase 100*, NCU	Chase et al., 1993	L13189
Rosa woodsii Lindl.	Rosaceae	*Soltis & Soltis 2410*, WS	Morgan et al., 1994	U06824
Poncirus trifoliata (L.) Raf.	Rutaceae	*Chase 117*, NCU	Chase et al., 1993	
Sabia sp.	Sabiaceae	*Qiu 91025*, NCU	Chase et al., 1993	L12662
Salix reticulata L.	Salicaceae	*Chase 840*, K	this paper	
Salvadora persica L.	Salvadoraceae	*Verdcourt s.n.*, K	Savolainen, unpubl.	
Koelreuteria paniculata Laxm.	Sapindaceae	*Chase 115*, NCU	this paper	
Manilkara zapota (L.) Royen	Sapotaceae	*Chase 129*, NCU	Albert et al., 1992	L01932
Sarracenia flava L.	Sarraceniaceae	*Chase 144*, NCU	Albert et al., 1992	L01952
Saxifraga integrifolia Hook.	Saxifragaceae	*Soltis & Soltis 2253*, WS	Morgan & Soltis, 1993	L01953
Scyphostegia borneensis Stapf	Scyphostegiaceae	*J. Davis s.n.*, BH	this paper	
Oubanguia alata Baker f.	Scytopetalaceae	*Gereau et al. 5202*, K	this paper	
Digitalis purpurea L.	Scrophulariaceae	none	Albert et al., 1992	L01902
Simmondsia chinensis (Link) C. K. Schneider	Simmondsiaceae	*Hoot s.n.*, F	this paper	
Nicotiana tabacum L.	Solanaceae	unknown	Lin et al., 1986	
Rhopalocarpus sp.	Sphaerosepalaceae	*Chase 906*, K	this paper	
Stachyurus praecox Sieb. & Zucc.	Stachyuraceae	*Chase 800*, K	this paper	
Staphylea trifoliata Payer	Staphyleaceae	*Chase 116*, NCU	this paper	
Styrax americana Lam.	Styraccaeae	*Kron 3002*, NCU	Kron & Chase, 1993	L12623

Appendix 7. Continued.

Species	Family	Voucher/source	Literature citation§	GenBank accession
Symplocus paniculata Miq.	Symplocaceae	*Kron 3005*, NCU	Kron & Chase, 1993	L12624
Suriana maritma L.	Surianaceae	unknown	Fernando et al., 1995	U07680
Tamarix pentandra Bunge	Tamaricaceae	*Chase 252*, NCU	this paper	
Tetacentron sinensis Oliv.	Tetracentraceae	*Qiu 90009*, NCU	Chase et al., 1993	L12668
Tetramerista sp.	Tetrameristaceae	*Coode 7925*, K	Morton et al., 1997	
Aquilaria beccariana Tiegh.	Thymelaeaceae	*Chase 1380*, K	this paper	
Camellia japonica L.	Theaceae	none	Kron & Chase, 1993	L12602
Platytheca verticellata Baill.	Tremandraceae	*Chase 179*, NCU	Chase et al., 1993	L01944
Trigonia nivea Cambess.	Trigoniaceae	*W. R. Anderson 13656*, MICH	Chase et al., 1993	
Tropaeolum majus L.	Tropaeolaceae	*Chase 113*, NCU	Price & Palmer, 1993	L14706
Viola sororia Willd.	Violaceae	none	Olmstead et al., 1992	L11674
Vitis aestivalis Michx.	Vitaceae	*Chase 226*, NCU	Albert et al., 1992	L01960
Qualea sp.	Vochysiaceae	*W. R. Anderson 13660*, MICH	Olmstead et al., 1992	U02730
Drimys winteri J. R. Forst. & G. Forst.	Winteraceae	*Qiu 90016*, NCU	Albert et al., 1992	L01905
Guaiacum sanctum L.	Zygophyllaceae	*W. R. Anderson s.n.*, MICH	Chase et al., 1993	

§ Publication in which an *rbc*L sequence for this taxon was first cited.

Abbreviatons used: Arb., arboretum; BG, botanical garden; G, garden; Natl., national; RBG, Royal Botanic Gardens; Trop., tropical; U, university; herbarium acronyms are the standard ones.

STATISTICAL SUMMARY OF SOME OF THE ACTIVITIES IN THE MISSOURI BOTANICAL GARDEN HERBARIUM, 1997

	Vascular	Bryophyte	Total
Acquisition of Specimens			
Staff Collections	20,611	6,523	27,134
Purchase	18,330	3,065	21,395
Exchange	29,942	3,992	33,934
Gifts	11,830	1,169	12,999
Total acquisitions	80,713	14,749	95,462
Mountings			
Newly mounted	49,706	12,095	61,801
Mounted when received	18,234*	0	18,234
Total specimens filed	67,940	12,095	80,035
Repairs			
Specimens repaired	27,241	n/a	27,241
Specimens stamped	1,881	n/a	1,881
Total repairs	29,122	n/a	29,122
Specimens sent			
On exchange	49,071	312	49,383
As gifts	15,560	1,075	16,635
Total	64,631	1,387	66,018
Loans sent			
Total transactions	410	27	437
Total specimens	32,846	4,586	37,432
To U.S. institutions			
Transactions	256	18	274
Specimens	22,374	2,856	25,230
To foreign institutions			
Transactions	154	9	163
Specimens	10,472	1,730	12,202
To student investigators			
Transactions	59	4	63
Specimens	10,160	509	10,669
To professional investigators			
Transactions	326	23	349
Specimens	22,553	4,077	26,630
Loans received			
Transactions	319	20	339
Specimens	33,697	2,204	35,901

* The 18,234 "mounted when received" vascular plants are specimens of Chinese plants purchased directly from China.

	From U.S.A.	From abroad	Total
Visitors	342	107	449

On 31 December 1997 the total number of mounted, accessioned specimens in the herbarium was 4,777,217 (4,482,859 vascular plants and 294,358 bryophytes).

The Garden's herbarium is closely associated with its database management system, TROPICOS. For example, many of the numbers in the preceding chart are taken from TROPICOS, since it is used as a herbarium management tool. Herbarium labels for newly collected specimens are generated through TROPICOS, and the information is retained there for further use. The charts below summarize some of the statistics from TROPICOS both for the calendar year 1997 and as year-end totals. Note that the specimen records in TROPICOS are primarily based on MO specimens, meaning that about seventeen percent of the bryophytes and twenty-six percent of the vascular plants in the herbarium are now computerized, with an overall total of about twenty-six percent. Distributional records are taken both from herbarium specimens and from literature records, and these are distinguished in TROPICOS. Similarly, information concerning types is taken both from the literature (protologues) and from specimens.

TROPICOS is essentially complete for the names of mosses, except forms, and contains a few thousand records for hepatics, for which no comprehensive effort has yet been undertaken. The 1997 additions to the names for bryophytes, 504, reflects pretty accurately the number of nova published for that group.

TROPICOS records—1997 additions

	Bryophytes	Vascular Plants	Total
Specimens	7,685	92,778	100,463
Names	504	24,545	25,049
Synonyms	944	15,725	16,669
Distributions	1,869	22,545	24,414
Types	123	16,475	16,598
Bibliography	1,348	2,399	3,747

TROPICOS records—Year-End 1997 Totals

	Bryophytes	Vascular Plants	Total
Specimens	50,338	1,179,217	1,229,555
Names	93,121	697,741	790,862
Synonyms	57,614	335,957	393,571
Distributions	36,330	692,513	728,843
Types	6,671	208,981	215,652
Bibliography	18,284	53,178	71,462
Specimens in herbarium	294,358	4,482,859	4,777,217
Percent computerized	17	26	26

—Marshall R. Crosby

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